AP Physics C: Electricity & Magnetism
1999 Scoring Guidelines

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1999 Physics C Solutions | **Distribution of points**

E & M 1 (15 points)

(a) 4 points

For using the relationship between potential and charge — 1 point

$V = \dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{r}$

Solving for Q:

$Q = 4\pi\epsilon_0 Vr$

For correct substitutions for the potential and radius — 1 point

$Q_0 = 4\pi\epsilon_0(-2000\text{ V})(0.20\text{ m})$ or $(-2000\text{ V})(0.20\text{ m})/\left(9\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)$

$Q_0 = -1600\pi\epsilon_0\text{ C}$ or $-4.4\times10^{-8}\text{ C}$

For the correct magnitude of Q_0 — 1 point

For the negative sign — 1 point

(b) 5 points

i. For indicating that the electric field is zero — 1 point

ii. The charge on the sphere can be treated as a point charge at its center

$E = \dfrac{1}{4\pi\epsilon_0}\dfrac{Q_0}{r^2}$

$E = \left(9\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(\dfrac{4.4\times10^{-8}\text{ C}}{r^2}\right)$

$E = \dfrac{396}{r^2}\dfrac{\text{N}}{\text{C}}$ or $\dfrac{400}{r^2}\dfrac{\text{N}}{\text{C}}$ where r is in meters

For any of the above expressions for E — 1 point

iii. For indicating that the electric field is zero — 1 point

iv. For indicating that the electric field is zero — 1 point

For having all four answers correct OR for some mention of using the enclosed charge OR for some mention of Gauss' law — 1 point

E & M 1 (continued)

(c) 3 points

$$\Delta V = V_b - V_a = -\int_a^b E\,dr$$

For recognition of the need to take the difference of the potentials at radii a and b, or for writing the definite integral (with limits) — 1 point

$$|\Delta V| = \frac{Q_0}{4\pi\epsilon_0}\int_a^b \frac{dr}{r^2}$$

$$= \frac{Q_0}{4\pi\epsilon_0}\left(\frac{1}{r}\right)\Big|_a^b$$

$$|\Delta V| = \frac{Q_0}{4\pi\epsilon_0}\left(\frac{1}{b} - \frac{1}{a}\right)$$

For correct substitution of variables or numerical values for Q_0, a, and b — 1 point

For the correct answer — 1 point

$$|\Delta V| = \frac{5Q_0}{8\pi\epsilon_0} \quad \text{or} \quad 1000\ \text{V}$$

(Alternate solution) — *(Alternate points)*

For recognition of the need to take the difference of the potentials at radii a and b — *1 point*

$$\Delta V = V_b - V_a$$

$$\Delta V = \frac{Q_0}{4\pi\epsilon_0}\left(\frac{1}{r_b}\right) - \frac{Q_0}{4\pi\epsilon_0}\left(\frac{1}{r_a}\right)$$

For correct substitution of Q_0, a, and b — *1 point*

$$\Delta V = \frac{Q_0}{4\pi\epsilon_0}\left(\frac{1}{b} - \frac{1}{a}\right)$$

For the correct answer — *1 point*

$$|\Delta V| = \frac{5Q_0}{8\pi\epsilon_0} \quad \text{or} \quad 1000\ \text{V}$$

(Alternate solution) — *(Alternate points)*

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

For using the above relationship — *1 point*

For substituting Q_0 from part (a) and C from part (d) alternate solution — *1 point*

For the correct answer — *1 point*

$$|\Delta V| = \frac{5Q_0}{8\pi\epsilon_0} \quad \text{or} \quad 1000\ \text{V}$$

Distribution of points

E & M 1 (continued)

(d) 2 points

$C = \frac{Q_0}{V}$

For using the above relationship — 1 point

For substituting Q_0 from part (a) and ΔV from part (c) — 1 point

$C = \frac{4.4 \times 10^{-8}\ \text{C}}{1000\ \text{V}}$

$C = 4.4 \times 10^{-11}\ \text{F}$

(Alternate solution) — *(Alternate points)*

For writing the equation for the capacitance of the spherical capacitor — *1 point*

$C = \frac{4\pi\epsilon_0 ab}{b - a}$

$C = \frac{(0.02\ \text{m})(0.04\ \text{m})}{\left(9 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)(0.04\ \text{m} - 0.02\ \text{m})}$

For the correct answer — *1 point*

$C = 4.4 \times 10^{-11}\ \text{F}$

For correct units on two answers and no incorrect units — 1 point

Distribution of Points

E & M 2 (15 points)

(a) 5 points

For using Faraday's law for a loop — 1 point

$\mathcal{E} = -\dfrac{d\phi}{dt}$ or $\mathcal{E} = -\dfrac{\Delta\phi}{\Delta t}$

For relating magnetic flux to magnetic field and area — 1 point

$\dfrac{d\phi}{dt} = A\dfrac{dB}{dt}$ or $\dfrac{\Delta\phi}{\Delta t} = A\dfrac{\Delta B}{\Delta t}$

For using the proper expression for the area of a loop — 1 point

$A = \pi r^2$

$\mathcal{E} = \pi r^2 \dfrac{dB}{dt}$ or $\mathcal{E} = \pi r^2 \dfrac{\Delta B}{\Delta t}$

For using the correct radius, i.e. the radius of the field — 1 point

$\mathcal{E} = \pi(0.6\ \text{m})^2(0.40\ \text{T/s})$

For computing the correct answer — 1 point

$\mathcal{E} = 0.45\ \text{V}$

(b) 3 points

For any statement of Ohm's law — 1 point

$V = IR$

Solving for the current:

$I = V/R = \mathcal{E}/R$

$I = (0.45\ \text{V})/(5.0\ \Omega)$

For computing the correct answer — 1 point

$I = 0.090\ \text{A}$

For indicating a clockwise direction for the current — 1 point

(c) 3 points

For relating the energy dissipated to the power in the resistor — 1 point

$E = \int P\,dt$ or $E = Pt$

For an expression for electric power — 1 point

$P = I^2R$ or $\dfrac{V^2}{R}$ or IV

Example using $P = I^2R$:

$E = I^2Rt$

$E = (0.090\ \text{A})^2(5.0\ \Omega)(15\ \text{s})$

For computing the correct answer — 1 point

$E = 0.61\ \text{J}$

	Distribution of Points
E & M 2 (continued)	
(d) 3 points	
For stating that the brightness of the bulb will be less	1 point
For indicating that the reduction in brightness is due to a decrease in current or a decrease in the emf	1 point
For indicating that the decrease in current or emf, or the reduction in brightness, is due to a decrease in the area of the loop or a decrease in the changing flux	1 point
For using correct units with three numerical answers	1 point

Distribution of points

E & M 3 (15 points)

(a) 3 points

The charge on any section of the ring is equidistant from a point on the x-axis, so one can write an equation in terms of the single distance r

For a correct expression of the potential — 1 point

$$= \frac{1}{4\pi\epsilon_0}\frac{dq}{r} \quad \text{or} \quad \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$$

For a correct expression for the distance of the charge from location x — 1 point

$$r = \sqrt{x^2 + R^2}$$

For the correct answer — 1 point

$$= \frac{1}{4\pi\epsilon_0}\frac{Q}{\sqrt{x^2 + R^2}}$$

Alternate solution — *Alternate points*

For correctly expressing the potential as an integral of the electric field — *1 point*

$$dV = -\int E\, dr$$

For a correct expression for the field — *1 point*

$$dV = -\int \frac{1}{4\pi\epsilon_0}\frac{Qx}{\left(x^2 + R^2\right)^{3/2}}\, dx$$

For correctly integrating to get the final answer — *1 point*

$$= \frac{1}{4\pi\epsilon_0}\frac{Q}{\sqrt{x^2 + R^2}}$$

(b)

i. 3 points

$$E = -\frac{dV}{dr}$$

For using the above relationship — 1 point

For taking the derivative with respect to x — 1 point

For using the expression for V obtained in part (a) — 1 point

$$E_x = -\frac{d}{dx}\left(\frac{1}{4\pi\epsilon_0}\frac{Q}{\sqrt{x^2 + R^2}}\right)$$

$$E_x = \frac{1}{4\pi\epsilon_0}\frac{Qx}{\left(x^2 + R^2\right)^{3/2}}$$

E & M 3 (continued)

(b) (continued)
i. (continued)

Alternate solution *Alternate points*

Calculating the field by integration:

$E = \int dE_x = \int dE\cos\theta$, where θ is the angle between the x-axis and the distance vector $\mathbf{r}$

For using the horizontal component of the field	*1 point*
For using a correct expression of Coulomb's law	*1 point*

$$E = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}$$

For indicating that the integral is over the charge *1 point*

$$E_x = \int \frac{1}{4\pi\epsilon_0}\frac{dq}{r^2}\cos\theta$$

Substituting $\cos\theta = x/r$ and $r = \sqrt{x^2 + R^2}$

$$E_x = \frac{1}{4\pi\epsilon_0}\frac{Q}{\left(x^2 + R^2\right)^{3/2}}\int_0^Q dq$$

$$E_x = \frac{1}{4\pi\epsilon_0}\frac{Qx}{\left(x^2 + R^2\right)^{3/2}}$$

ii. 1 point

For any indication that the y- and z-components are zero or cancel 1 point

E & M 3 (continued)

(c)

i. 2 points

For taking the derivative of E with respect to x and setting it equal to zero — 1 point

$$\frac{dE_x}{dx} = \frac{d}{dx}\left(\frac{1}{4\pi\epsilon_0}\frac{Qx}{\left(x^2 + R^2\right)^{3/2}}\right) = 0$$

$$\frac{Q}{4\pi\epsilon_0}\left(\frac{1}{\left(x^2 + R^2\right)^{3/2}} + \left(-\frac{3}{2}\right)\frac{2x^2}{\left(x^2 + R^2\right)^{5/2}}\right) = 0$$

$$\frac{1}{\left(x^2+R^2\right)^{3/2}} - \frac{3x^2}{\left(x^2+R^2\right)^{5/2}} = 0$$

$$\frac{1}{\left(x^2+R^2\right)^{3/2}} = \frac{3x^2}{\left(x^2+R^2\right)^{5/2}}$$

$$1 = \frac{3x^2}{x^2+R^2}$$

$$3x^2 = x^2 + R^2$$

$x = \pm\dfrac{R}{\sqrt{2}}$ and the maximum occurs at the positive value of x

For the correct answer — 1 point

$$x = +\frac{R}{\sqrt{2}}$$

ii. 1 point

For substituting the answer from part (c)i into the given expression for the electric field — 1 point

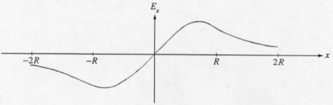
$$E_{x\,\max} = \frac{1}{4\pi\epsilon_0}\frac{Q\left(R/\sqrt{2}\right)}{\left(\left(R/\sqrt{2}\right)^2 + R^2\right)^{3/2}}$$

$$E_{x\,\max} = \frac{1}{4\pi\epsilon_0}\frac{2Q}{3\sqrt{3}R^2}$$

Distribution of points

E & M 3 (continued)

(d) 3 points



For a curve in the first quadrant displaying a single positive maximum	1 point
For a curve passing through the origin	1 point
For the negative reflection of the first quadrant curve in the third quadrant	1 point

(e) 2 points

For any statement that describes the subsequent motion as oscillating, periodic etc. 2 points

One point was awarded for a statement that only described the electron as moving toward the ring or along the x-axis.