



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

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

Solving for Q :

$$Q = 4\pi\epsilon_0 Vr$$

For correct substitutions for the potential and radius

$$Q_0 = 4\pi\epsilon_0 (-2000 \text{ V})(0.20 \text{ m}) \quad \text{or} \quad (-2000 \text{ V})(0.20 \text{ m}) / (9 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)$$

$$Q_0 = -1600\pi\epsilon_0 \text{ C} \quad \text{or} \quad -4.4 \times 10^{-8} \text{ C}$$

For the correct magnitude of Q_0

For the negative sign

1 point

1 point

1 point

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

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

$$E = (9 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2) \left(\frac{4.4 \times 10^{-8} \text{ C}}{r^2} \right)$$

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

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

1999 Physics C Solutions

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)

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

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

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

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

For the correct answer

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

(Alternate solution)

For recognition of the need to take the difference of the potentials at radii a and b

$$\Delta V = V_b - V_a$$

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

For correct substitution of Q_0 , a , and b

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

For the correct answer

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

(Alternate solution)

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

For using the above relationship

For substituting Q_0 from part (a) and C from part (d) alternate solution

For the correct answer

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

Distribution
of points

1 point

1 point

1 point

(Alternate points)

1 point

1 point

1 point

(Alternate points)

1 point

1 point

1 point

1999 Physics C Solutions

E & M 1 (continued)

(d) 2 points

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

For using the above relationship

For substituting Q_0 from part (a) and ΔV from part (c)

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

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

(Alternate solution)

For writing the equation for the capacitance of the spherical capacitor

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

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

For the correct answer

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

For correct units on two answers and no incorrect units

Distribution
of points

1 point

1 point

(Alternate points)

1 point

1 point

1 point

1999 Physics C Solutions

E & M 2 (15 points)

(a) 5 points

For using Faraday's law for a loop

$$\mathcal{E} = -\frac{d\phi}{dt} \quad \text{or} \quad \mathcal{E} = -\frac{\Delta\phi}{\Delta t}$$

For relating magnetic flux to magnetic field and area

$$\frac{d\phi}{dt} = A \frac{dB}{dt} \quad \text{or} \quad \frac{\Delta\phi}{\Delta t} = A \frac{\Delta B}{\Delta t}$$

For using the proper expression for the area of a loop

$$A = \pi r^2$$

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

For using the correct radius, i.e. the radius of the field

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

For computing the correct answer

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

(b) 3 points

For any statement of Ohm's law

$$V = IR$$

Solving for the current:

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

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

For computing the correct answer

$$I = 0.090 \text{ A}$$

For indicating a clockwise direction for the current

(c) 3 points

For relating the energy dissipated to the power in the resistor

$$E = \int P \, dt \quad \text{or} \quad E = Pt$$

For an expression for electric power

$$P = I^2 R \quad \text{or} \quad \frac{V^2}{R} \quad \text{or} \quad IV$$

Example using $P = I^2 R$:

$$E = I^2 R t$$

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

For computing the correct answer

$$E = 0.61 \text{ J}$$

Distribution
of Points

1 point

1 point

1 point

1 point

1 point

1 point

1 point

1 point

1 point

1 point

1 point

1999 Physics C Solutions

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

1999 Physics C Solutions

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

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

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

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

For the correct answer

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

Alternate solution

For correctly expressing the potential as an integral of the electric field

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

For a correct expression for the field

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

For correctly integrating to get the final answer

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

(b)

i. 3 points

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

For using the above relationship

For taking the derivative with respect to x

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

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

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

Distribution
of points

1 point

1 point

1 point

Alternate points
1 point

1 point

1 point

1 point

1 point

1 point

1999 Physics C Solutions

E & M 3 (continued)

(b) (continued)

i. (continued)

Alternate solution

Calculating the field by integration:

$$E = \int dE_x = \int dE \cos \theta, \text{ where } \theta \text{ is the angle between the } x\text{-axis and}$$

the distance vector $\mathbf{r}$

For using the horizontal component of the field

For using a correct expression of Coulomb's law

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

For indicating that the integral is over the charge

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

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

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

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

ii. 1 point

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

Distribution
of points*Alternate points*

1 point

1 point

1 point

1 point

1999 Physics C Solutions

E & M 3 (continued)

Distribution
of points

(c)

i. 2 points

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

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

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

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

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

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

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

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

For the correct answer

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

1 point

ii. 1 point

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

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

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

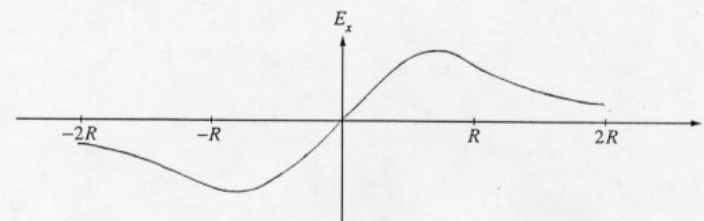
1 point

1999 Physics C Solutions

E & M 3 (continued)

Distribution
of points

(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.