



AP Physics C: Electricity & Magnetism 2000 Scoring Guidelines

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2000 Physics C Solutions

Distribution
of points

E&M. 1 (15 points)

(a) 4 points

Since brightness is proportional to the power dissipated by a bulb, the answer may be found by solving the circuit to determine the power dissipated by each bulb. For example,

$$\frac{1}{R_p} = \frac{1}{12\ \Omega} + \frac{1}{6\ \Omega} = \frac{3}{12\ \Omega}, \text{ where } R_p \text{ is the resistance of the parallel combination of resistors}$$

$$R_p = 4\ \Omega$$

$$I_A = \frac{\mathcal{E}}{R_A + R_p} = \frac{42\ \text{V}}{10\ \Omega + 4\ \Omega} = 3\ \text{A}$$

$$I_B = \frac{V_p}{R_B} = \frac{I_A R_p}{R_B} = \frac{(3\ \text{A})(4\ \Omega)}{12\ \Omega} = 1\ \text{A}$$

$$I_C = \frac{V_p}{R_C} = \frac{I_A R_p}{R_C} = \frac{3 \cdot 4(3\ \text{A})(4\ \Omega)}{6\ \Omega} = 2\ \text{A}$$

$$P_A = I_A^2 R_A = (3\ \text{A})^2 (10\ \Omega) = 90\ \text{W}$$

$$P_B = I_B^2 R_B = (1\ \text{A})^2 (12\ \Omega) = 12\ \text{W}$$

$$P_C = I_C^2 R_C = (2\ \text{A})^2 (6\ \Omega) = 24\ \text{W}$$

For correct ordering, i.e., bulb *A* is brighter than bulb *C*, which is brighter than bulb *B* (Partial credit of 1 point given for incorrect answer but with an indication that bulb *A* is brightest or that bulb *C* is brighter than bulb *B*.)

For a correct explanation, which can be by a quantitative solution for the currents and powers as above, or by a qualitative approach that notes that all the current in the circuit flows through bulb *A*, then branches in such a way that bulb *C* receives more current than bulb *B*.

3 points

1 point

(b)

i. 3 points

Immediately after the switch is closed there is no current in the inductor so the circuit consists of resistors *A* and *B* in series with the source of emf.

$$\text{For } I_C = 0$$

For recognition that $I_A = I_B$ and they are nonzero

$$\text{For correct numerical answers for } I_A \text{ and } I_B, \text{ i.e., } I_A = I_B = \frac{42\ \text{V}}{10\ \Omega + 12\ \Omega} = 1.91\ \text{A}$$

1 point

1 point

1 point

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E&M. 1 (continued)

(b) (continued)

ii. 3 points

A long time after the switch is closed, the potential difference across the inductor is zero, so the circuit is essentially the same as in part (a)

For recognizing that $V_L = 0$

For correct currents, the same as in part (a), i.e., $I_A = 3 \text{ A}$, $I_B = 1 \text{ A}$, $I = 2 \text{ A}$
(If currents not computed in part (a), they could be computed here.)

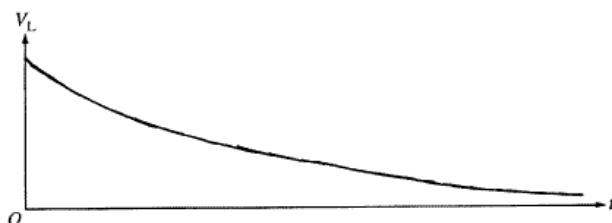
Distribution
of points

1 point
2 points

Unit point: For expressing all currents in (b) in correct units of amperes

1 point

(c) 2 points



Attributes of correct curve:

1. Starts at a nonzero but finite point on the vertical axis
2. Smooth
3. Concave upward
4. Has asymptote equal to zero

For a correct curve with all four attributes

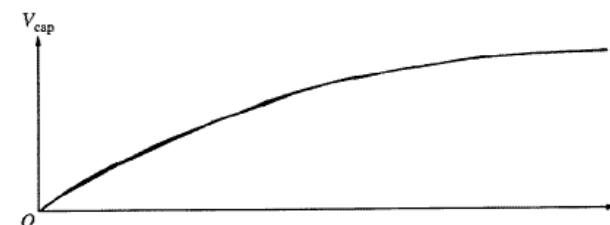
2 points

Partial credit of 1 point for curve with flaws but at least two correct attributes

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E&M. 1 (continued)

(d) 2 points



Attributes of correct curve:

1. Starts at zero
2. Smooth
3. Concave downward
4. Has finite but nonzero asymptote

For a correct curve with all four attributes

Distribution
of points

2 points

Partial credit of 1 point for curve with flaws but at least two correct attributes

2000 Physics C Solutions

E&M. 2 (15 points)

(a)

i. 6 points

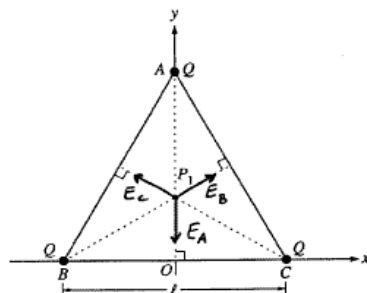


Figure 1

One point for each arrow drawn in the correct direction

3 points

For not having all arrows approximately the same length, deduction of 1 point

For not having all arrows start at P_1 , deduction of 1 point

For having one or more extra vectors, deduction of 1 point

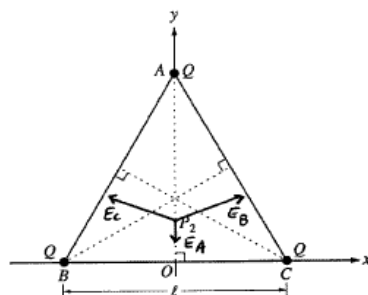


Figure 2

One point for each arrow drawn in the correct direction

3 points

For not having lengths of arrows such that $E_C = E_B > E_A$, deduction of 1 point

For not having all arrows start at P_2 , deduction of 1 point

For having one or more extra vectors, deduction of 1 point

Distribution
of points

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E&M. 2 (continued)

(a) (continued)

ii. 3 points

	Greater than at P_1	Less than at P_1	The same as at P_1
E_A		✓	
E_B	✓		
E_C	✓		

One point for having check mark or other indicator in each correct box

3 points

(b) 1 point

For an indication that the x-components of the field vectors due to particles C and B cancel each other due to the symmetry created by having a vertex of the triangle on the y-axis

1 point

(c) 3 points

For an indication that the potential is the sum of the potentials due to the individual charges

1 point

$$V = \sum_i \frac{kQ_i}{r_i} = k \left(\frac{Q_A}{r_A} + \frac{Q_B}{r_B} + \frac{Q_C}{r_C} \right)$$

For recognition that the terms due to the particles at B and C are equal

1 point

$$V = k \left(\frac{Q_A}{r_A} + \frac{2Q}{r_B} \right)$$

For correct substitutions for Q 's and r 's and correct answer

1 point

$$V = \frac{1}{4\pi\epsilon_0} \left(\frac{Q}{\frac{\sqrt{3}l}{2} - y} + \frac{2Q}{\sqrt{\frac{l^2}{4} + y^2}} \right), \text{ or equivalent}$$

Distribution
of points

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E&M. 2 (continued)

(d) 2 points

Since $E_y = -\frac{d}{dy}V(y)$, to find the y coordinates of the points on the y -axis at which the electric field is zero, take the derivative of the expression in part (c) with respect to y , set the expression equal to zero and solve for y .

For recognition that E is a derivative of V

For recognition that $\frac{dV}{dy} = 0$

Distribution
of points

1 point
1 point

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E&M. 3 (15 points)

(a)

i. 3 points

For a correct statement of Gauss's law

$$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{Q}{\epsilon}$$

For expressing the permittivity of the oil in terms of the dielectric constant κ
 $\epsilon = \kappa\epsilon_0$

For a correct expression for the electric field in the oil

$$E(2\pi rL) = \frac{Q}{\kappa\epsilon_0}$$

$$E = \frac{Q}{2\pi\kappa\epsilon_0 rL}$$

ii. 2 points

For a correct statement of Gauss's law in the space outside the outer shell

$$\oint \mathbf{E} \cdot d\mathbf{A} = 0$$

For stating that the electric field is zero in this region

$$E = 0$$

(b)

i. 3 points

For an expression for the electric potential between the two shells

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

For substituting the expression for the electric field between the shells

$$\Delta V = \frac{Q}{2\pi\kappa\epsilon_0 L} \int_a^b \frac{dr}{r}$$

For a correct expression for the electric potential difference between the shells

$$\Delta V = \frac{Q}{2\pi\kappa\epsilon_0 L} \ln\left(\frac{b}{a}\right)$$

Distribution
of points

1 point

1 point

1 point

1 point

1 point

1 point

1 point

1 point

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E&M. 3 (continued)

(b) (continued)

ii. 2 points

For an expression for the capacitance in terms of Q and ΔV

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

Substituting the expression for ΔV from (b)i:

$$C = \frac{Q}{\frac{Q}{2\pi\kappa\epsilon_0 L \ln\left(\frac{b}{a}\right)}}$$

For a correct expression for the capacitance

$$C = \frac{2\pi\kappa\epsilon_0 L}{\ln\left(\frac{b}{a}\right)}$$

(3)

i. 3 points

For a correct statement of Ampere's law

$$\oint \mathbf{B} \cdot d\boldsymbol{\ell} = \mu_0 I$$

For substituting the current through the inner shell

$$B(2\pi r) = \mu_0 \left(\frac{\mathcal{E}}{R} \right)$$

For a correct expression for the magnetic field between the shells

$$B = \frac{\mu_0 \mathcal{E}}{2\pi r R}$$

ii. 2 points

For the correct substitution of the total current through both shells in to Ampere's law

$$B(2\pi r) = \mu_0 \left(\frac{4\mathcal{E}}{R} \right)$$

For a correct expression for the magnetic field around the outer shell

$$B = \frac{2\mu_0 \mathcal{E}}{\pi r R}$$

Distribution
of points

1 point

1 point

1 point

1 point

1 point

1 point

1 point