# AP Physics C: Electricity & Magnetism
# 2000 Scoring Guidelines



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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,

$\frac{1}{R_p} = \frac{1}{12\ \Omega} + \frac{1}{6\ \Omega} = \frac{3}{12\ \Omega}$, where $R_p$ 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 $B$ — 3 points

(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 $B$. — 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.

For $I_C = 0$ — 1 point

For recognition that $I_A = I_B$ and they are nonzero — 1 point

For correct numerical answers for $I_A$ and $I_B$, i.e., $I_A = I_B = \frac{42\ \text{V}}{10\ \Omega + 12\ \Omega} = 1.91\ \text{A}$ — 1 point

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)

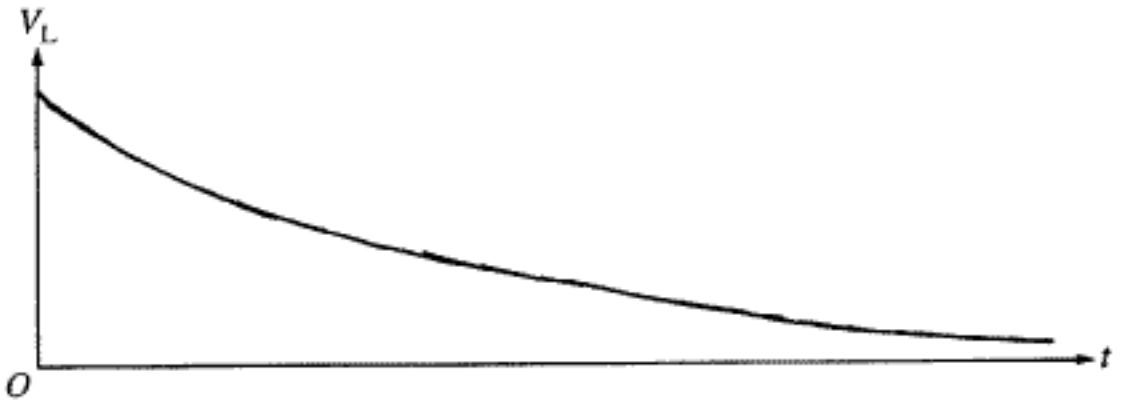
For recognizing that $V_L = 0$ 1 point

For correct currents, the same as in part (a), i.e., $I_A = 3$ A, $I_B = 1$ A, $I = 2$ A 2 points

(If currents not computed in part (a), they could be computed here.)

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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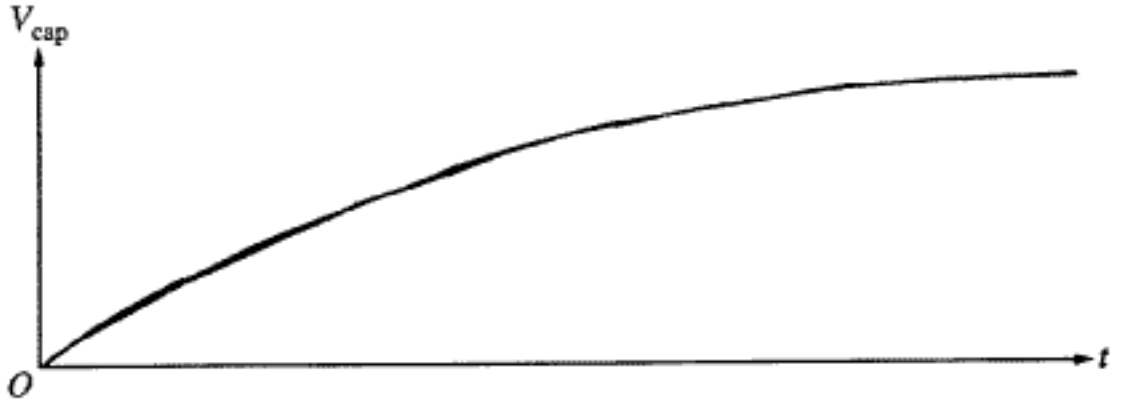
**Distribution of points**

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 — 2 points

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

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**Distribution of points**

E&M. 2 (15 points)

(a)

i. 6 points

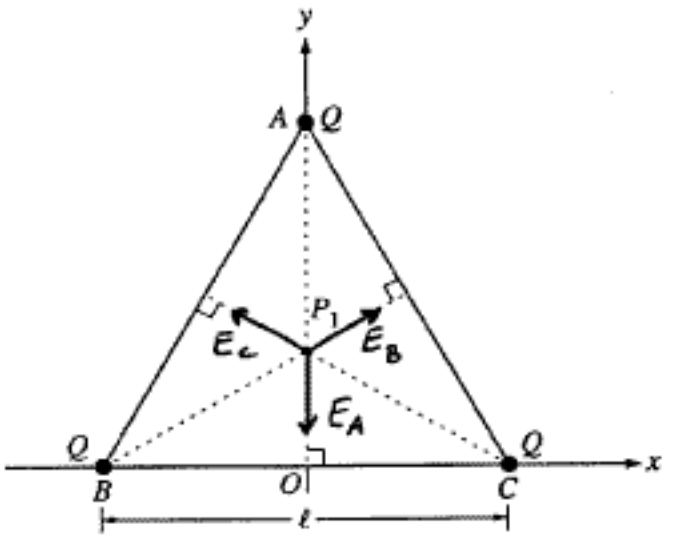


Figure 1

- 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

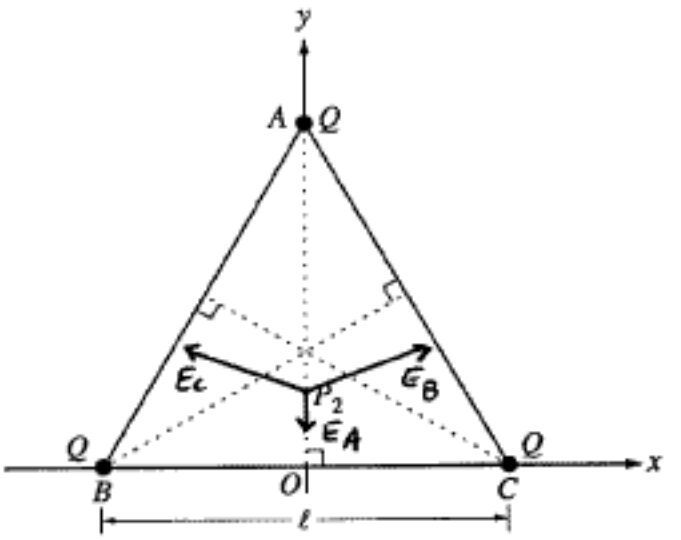


Figure 2

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

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

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{\frac{\sqrt{3}\ell}{2} - y} + \frac{2Q}{\sqrt{\frac{\ell^2}{4} + y^2}}\right), \text{ or equivalent}$$

**Distribution of points**

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 $V$ — 1 point

For recognition that $\frac{dV}{dy} = 0$ — 1 point

**2000 Physics C Solutions** | **Distribution of points**

E&M. 3 (15 points)

(a)

i. 3 points

For a correct statement of Gauss's law — 1 point

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

For expressing the permittivity of the oil in terms of the dielectric constant $\kappa$ — 1 point

$$\epsilon = \kappa\epsilon_0$$

For a correct expression for the electric field in the oil — 1 point

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

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

ii. 2 points

For a correct statement of Gauss's law in the space outside the outer shell — 1 point

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

For stating that the electric field is zero in this region — 1 point

$$\mathbf{E} = 0$$

(b)

i. 3 points

For an expression for the electric potential between the two shells — 1 point

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

For substituting the expression for the electric field between the shells — 1 point

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

For a correct expression for the electric potential difference between the shells — 1 point

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

E&M. 3 (continued)

(b) (continued)

ii. 2 points

For an expression for the capacitance in terms of $Q$ and $\Delta V$ — 1 point

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

Substituting the expression for $\Delta V$ 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 — 1 point

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

(c)

i. 3 points

For a correct statement of Ampere's law — 1 point

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

For substituting the current through the inner shell — 1 point

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

For a correct expression for the magnetic field between the shells — 1 point

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

ii. 2 points

For the correct substitution of the total current through both shells in to Ampere's law — 1 point

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

For a correct expression for the magnetic field around the outer shell — 1 point

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