# 2000 Advanced Placement Program®
# Free-Response Questions



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The College Board

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## 2000 AP® PHYSICS C FREE-RESPONSE QUESTIONS

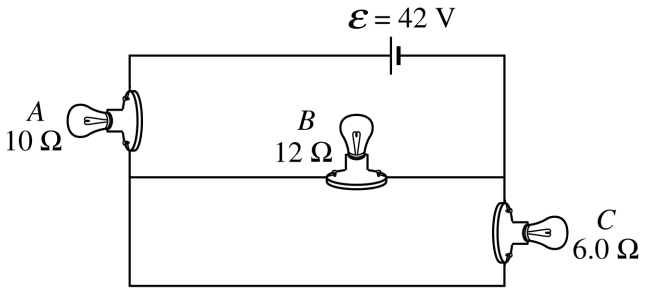
**PHYSICS C**

**Section II, ELECTRICITY AND MAGNETISM**

**Time—45 minutes**

**3 Questions**

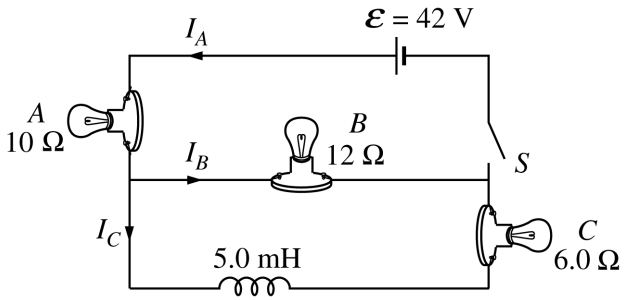
**Directions:** Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in the pink booklet in the spaces provided after each part, NOT in this green insert.




E & M 1.

Lightbulbs $A$, $B$, and $C$ are connected in the circuit shown above.

(a) List the bulbs in order of their brightness, from brightest to least bright. If any bulbs have the same brightness, state which ones. Justify your answer.




Now a switch $S$ and a 5.0 mH inductor are added to the circuit, as shown above. The switch is closed at time $t = 0$.

(b) Determine the currents $I_A$, $I_B$, and $I_C$ for the following times.

i. Immediately after the switch is closed

ii. A long time after the switch is closed



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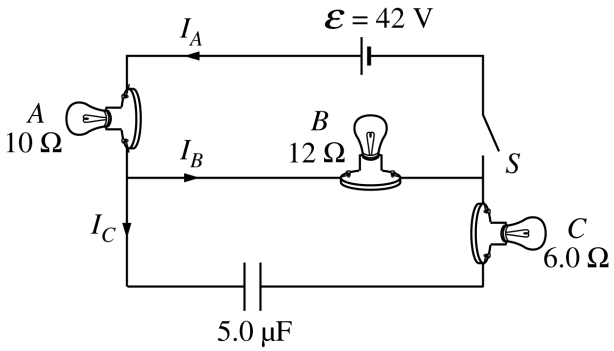
(c) On the axes below, sketch the magnitude of the potential difference $V_L$ across the inductor as a function of time, from immediately after the switch is closed until a long time after the switch is closed.


(d) Now consider a similar circuit with an uncharged 5.0 μF capacitor instead of the inductor, as shown above. The switch is again closed at time $t = 0$. On the axes below, sketch the magnitude of the potential difference $V_{cap}$ across the capacitor as a function of time, from immediately after the switch is closed until a long time after the switch is closed.

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E & M 2.

Three particles, $A$, $B$, and $C$, have equal positive charges $Q$ and are held in place at the vertices of an equilateral triangle with sides of length $\ell$, as shown in the figures below. The dotted lines represent the bisectors for each side. The base of the triangle lies on the $x$-axis, and the altitude of the triangle lies on the $y$-axis.

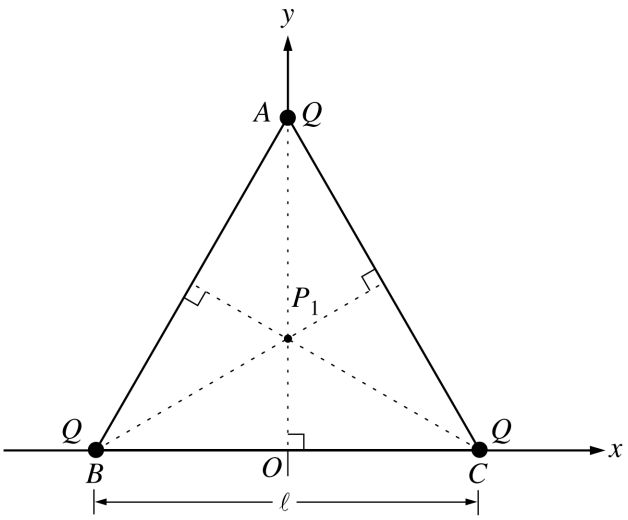


Figure 1

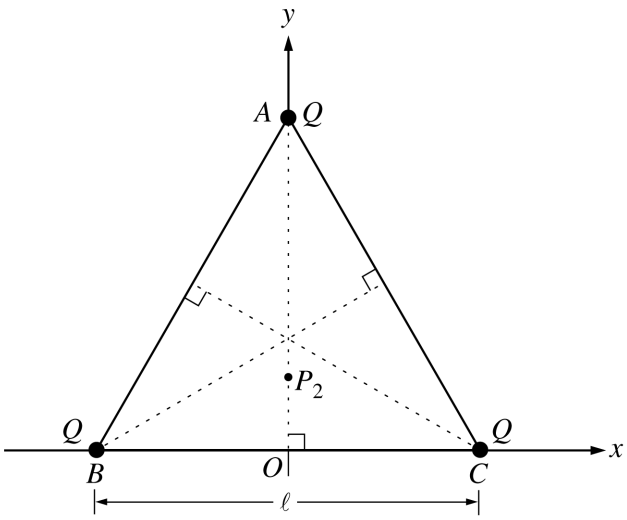


Figure 2

(a)

i. Point $P_1$, the intersection of the three bisectors, locates the geometric center of the triangle and is one point where the electric field is zero. On Figure 1 above, draw the electric field vectors $\mathbf{E}_A$, $\mathbf{E}_B$, and $\mathbf{E}_C$ at $P_1$ due to each of the three charges. Be sure your arrows are drawn to reflect the relative magnitude of the fields.

ii. Another point where the electric field is zero is point $P_2$ at $(0, y_2)$. On Figure 2 above, draw electric field vectors $\mathbf{E}_A$, $\mathbf{E}_B$, and $\mathbf{E}_C$ at $P_2$ due to each of the three point charges. Indicate below whether the magnitude of each of these vectors is greater than, less than, or the same as for point $P_1$.

| | Greater than at $P_1$ | Less than at $P_1$ | The same as at $P_1$ |
|---|---|---|---|
| $E_A$ | | | |
| $E_B$ | | | |
| $E_C$ | | | |



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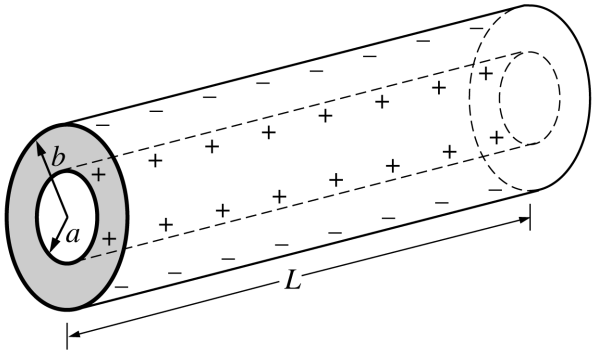
(b) Explain why the $x$-component of the total electric field is zero at any point on the $y$-axis.

(c) Write a general expression for the electric potential $V$ at any point on the $y$-axis inside the triangle in terms of $Q$, $\ell$, and $y$.

(d) Describe how the answer to part (c) could be used to determine the $y$-coordinates of points $P_1$ and $P_2$ at which the electric field is zero. (You do not need to actually determine these coordinates.)




E & M 3.

A capacitor consists of two conducting, coaxial, cylindrical shells of radius $a$ and $b$, respectively, and length $L >> b$. The space between the cylinders is filled with oil that has a dielectric constant $\kappa$. Initially both cylinders are uncharged, but then a battery is used to charge the capacitor, leaving a charge $+Q$ on the inner cylinder and $-Q$ on the outer cylinder, as shown above. Let $r$ be the radial distance from the axis of the capacitor.

(a) Using Gauss's law, determine the electric field midway along the length of the cylinder for the following values of $r$, in terms of the given quantities and fundamental constants. Assume end effects are negligible.

i. $a < r < b$

ii. $b < r << L$

(b) Determine the following in terms of the given quantities and fundamental constants.

i. The potential difference across the capacitor

ii. The capacitance of this capacitor

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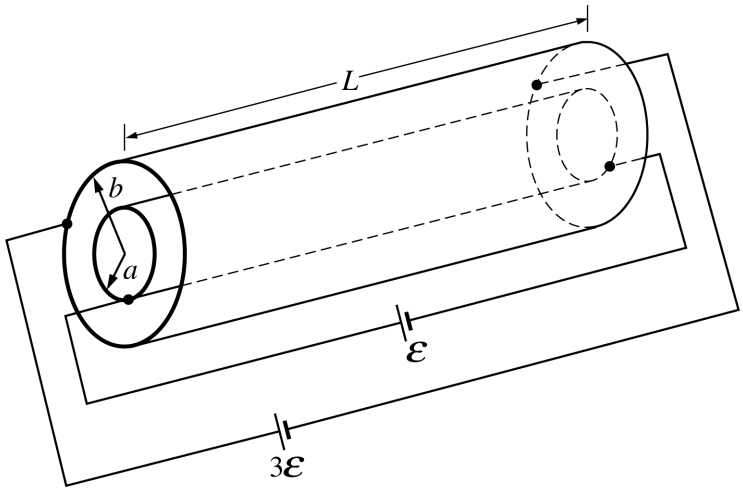


(c) Now the capacitor is discharged and the oil is drained from it. As shown above, a battery of emf $\mathcal{E}$ is connected to opposite ends of the inner cylinder and a battery of emf $3\mathcal{E}$ is connected to opposite ends of the outer cylinder. Each cylinder has resistance $R$. Assume that end effects and the contributions to the magnetic field from the wires are negligible. Using Ampere's law, determine the magnitude $B$ of the magnetic field midway along the length of the cylinders due to the current in the cylinders for the following values of $r$.

i. $a < r < b$

ii. $b < r << L$

# S T O P

**END OF SECTION II, ELECTRICITY AND MAGNETISM**

**IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON SECTION II, ELECTRICITY AND MAGNETISM, ONLY. DO NOT TURN TO ANY OTHER TEST MATERIALS.**