2000 AP® PHYSICS C FREE-RESPONSE QUESTIONS

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 ℓ, 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.

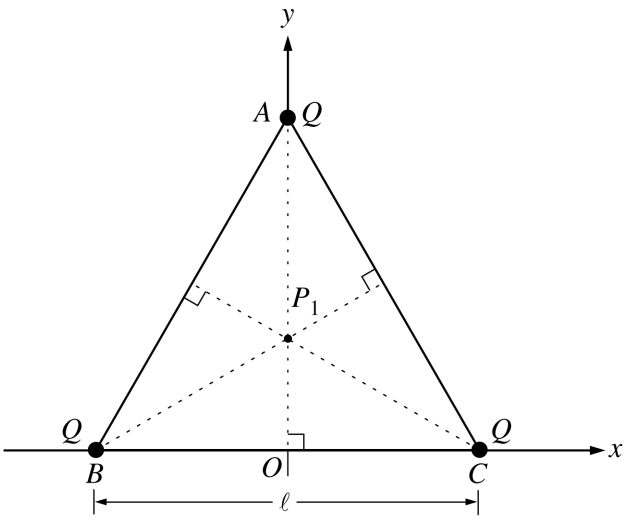

Figure 1

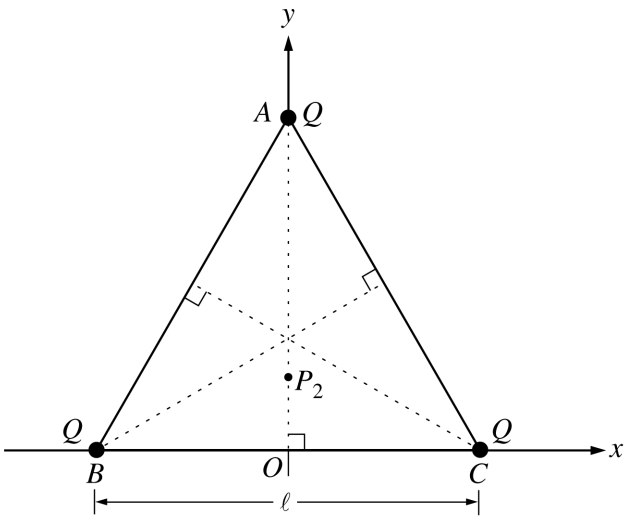

Figure 2

(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			

GO ON TO THE NEXT PAGE.

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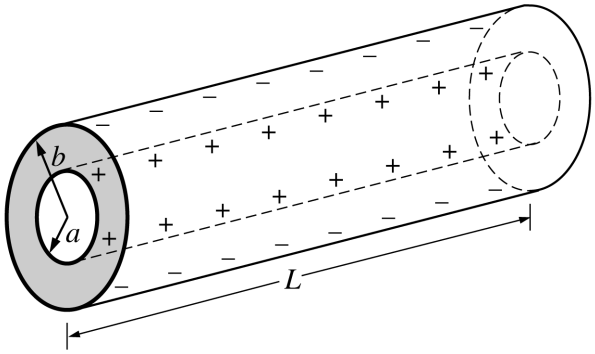
(b) Explain why the x-component of the total electric field is zero at any point on the y-axis.

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

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

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