AP Physics C: Electricity and Magnetism
2000 Student Samples

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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 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.

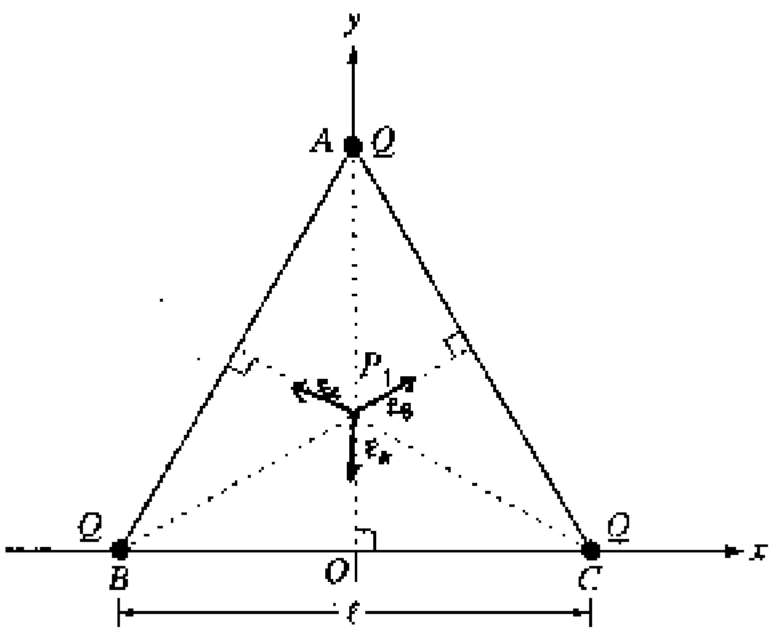


Figure 1

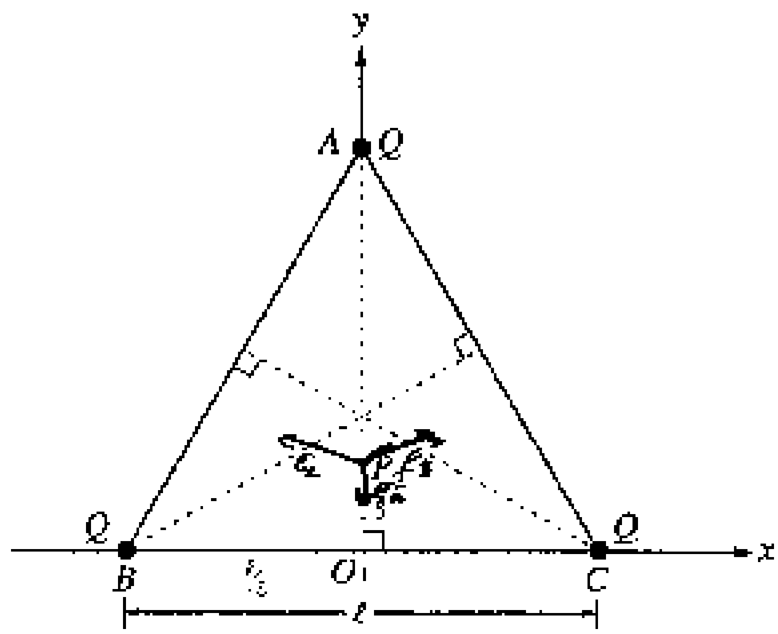


Figure 2

(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	No	Yes	No
E_B	Yes	No	No
E_C	Yes	No	No

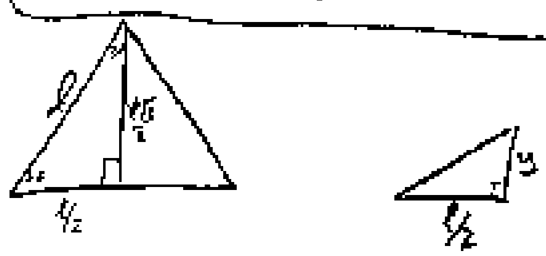
GO ON TO THE NEXT PAGE.

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

Because on the yes axis the x-component of the field from A will always be 0 since it is directly above. The x-components from B & C will cancel each other out since they are equidistant from whatever point on the y-axis is chosen and they are on opposite sides. Therefore, there is no x-component of the total electric field on 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.

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



$\ell^2 - \frac{\ell^2}{4} = \frac{3\ell^2}{4}$ $\quad$ $\sqrt{y^2 + \frac{\ell^2}{4}}$

(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.)

When the electric field is zero, the opposite of the derivative of the Voltage is equal to zero $\left(E = \frac{-dV}{dr}\right)$. Find the derivative of V, set it equal to zero, and solve for y to get the y-coordinates at which the electric field is zero.

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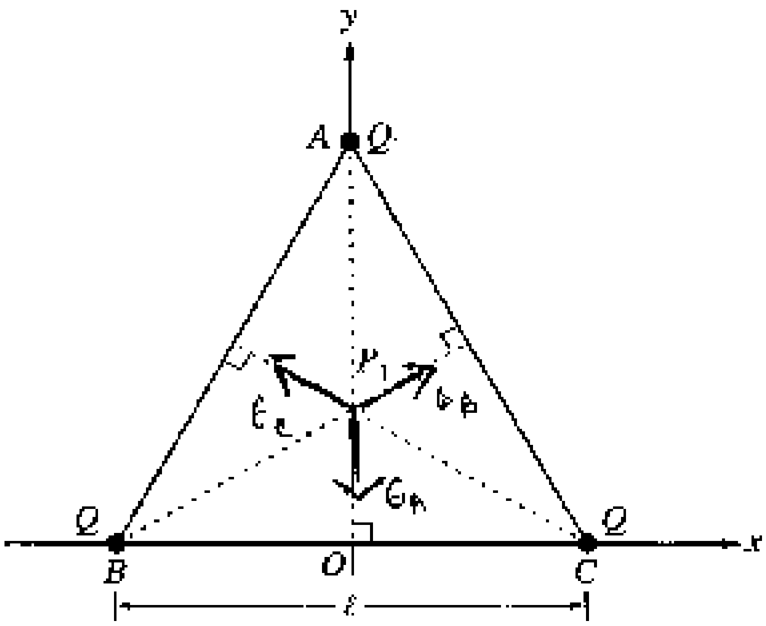

Figure 1

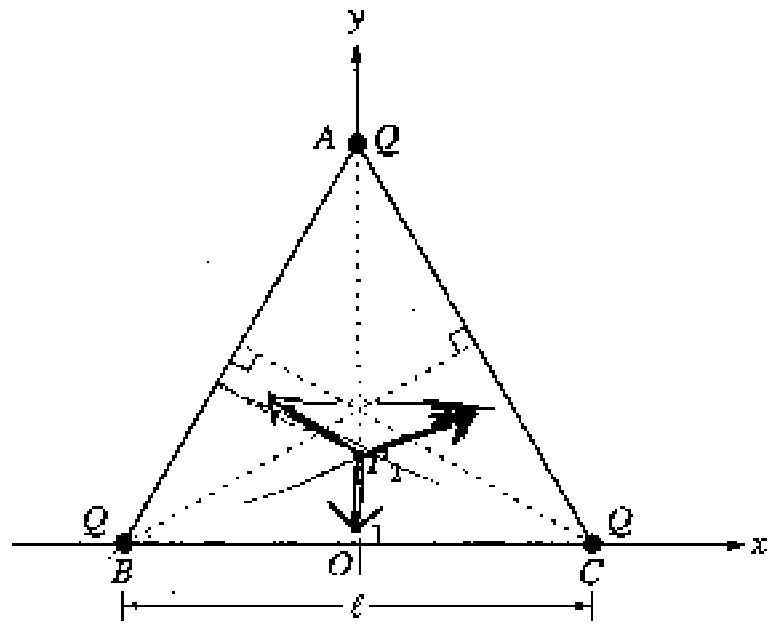

Figure 2

(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	✓		

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

the x-components of the E_B & E_C vectors will always be equal & opposite, and the x-component of the E_A vector is zero, so the vector sum of the 3 will always be zero.

(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.

distance from A $= \frac{\ell\sqrt{3}}{2} - y$

distance from B = distance from C $= \sqrt{\frac{\ell^2}{4} + y^2}$

voltage $= \frac{1}{4\pi\epsilon_0}\frac{Q}{R}$, and voltages are additive, so

$$V = \frac{1}{4\pi\epsilon_0} Q \left[\frac{1}{\ell\frac{\sqrt{3}}{2} - y} + \frac{2}{\sqrt{\frac{\ell^2}{4} + y^2}} \right]$$

(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.)

$\vec{E} = -\nabla V$; on the x-axis that means

$\vec{E} = -dV/dy$. if $|\vec{E}| = 0$,

$|-dV/dt| = 0$, so

we can take dV/dt, set it $= 0$, and solve.

GO ON TO THE NEXT PAGE.

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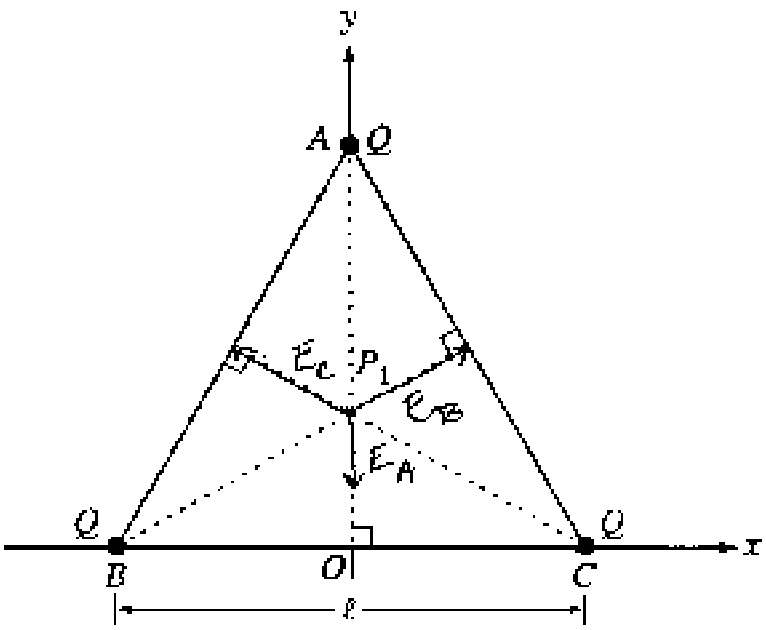

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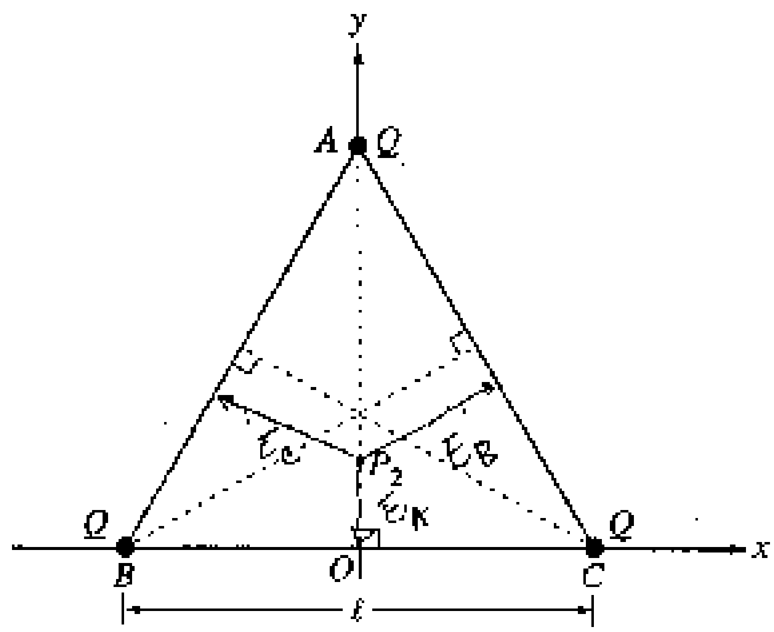

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	Greater than at P_1	Less than at P_1	The same as at P_1
E_A	Ec, EB		
E_B	EA		Ec
E_C	EA		EB

GO ON TO THE NEXT PAGE.

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

Because the magnitude of the x-component of E_B and the x-component E_C are equal all along the y-axis, but in opposite directions, $E_{Bx} + E_{Cx} = 0$. Also, along the y-axis, the x-component of E_A is always equal to zero

(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.

$$V = k\sum_i \frac{q_i}{r_i} = \boxed{k\left(\frac{Q}{y-\frac{\ell}{2}} + \frac{Q}{\sqrt{y^2+\left(\frac{\ell}{2}\right)^2}} + \frac{Q}{\sqrt{y^2+\left(\frac{\ell}{2}\right)^2}}\right)}$$

$$\boxed{V = k\left(\frac{Q}{y-\frac{\ell}{2}} + \frac{2Q}{\sqrt{y^2+\frac{\ell^2}{4}}}\right)}$$

(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.)

$E = -\frac{dV}{dr}$ Take the derivative of $V(y)$ in part (c) with respect to y and set it equal to zero. Then solve for y.

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