

GRIFFITHS ELECTRODYNAMICS SOLUTIONS

KALMAN KNIZHNIK

Problem 2.1

a) Twelve equal charges, q are situated at the corners of a regular 12-sided polygon (for instance, one on each numeral of a clock face.) What is the net force on a test charge Q at the center?

The force on Q must be 0 by symmetry. The x , y , and z components of the fields due to each charge cancel, so the force vanishes.

b) Suppose one of the 12 q 's is removed (the one at "6 o'clock"). What is the force on Q ? Explain your reasoning carefully.

Now it is like 10 of the charges cancel, the only one that doesn't cancel being the one directly opposite the missing charge. Thus, the force is

$$F = \frac{1}{4\pi\epsilon_0} \frac{qQ}{r^2} \quad \square \quad (1)$$

pointing in the direction of the missing charge. Here, r is the distance from the center to each charge.

c) Now 13 equal charges, q , are placed at the corners of a regular 13-sided polygon. What is the force on a test charge Q at the center.

Again, by symmetry, the answer is still 0.

d) If one of the 13 q 's is removed, what is the force on Q ? Explain your reasoning.

The same answer as in part b, equation 1, and for the same reason.

Problem 2.2

a) Find the electric field (magnitude and direction) a distance z above the midpoint between two equal charges, q , a distance d apart. Check that your result is consistent with what you'd expect when $z \gg d$.

The force would not have components in the y or x direction, if we put the charges in the $x - z$ plane, there is no y -component of the field at the point in question, and the x -components cancel. The z -component of the field is

$$\mathbf{E} = \frac{1}{4\pi\epsilon_0} \frac{2q}{z^2 + (d/2)^2} \sin(\theta) \hat{\mathbf{z}} = \frac{1}{4\pi\epsilon_0} \frac{2qz}{(z^2 + (d/2)^2)^{3/2}} \hat{\mathbf{z}} \quad \square \quad (2)$$

where the factor of 2 comes from adding up the two charges. When $z \gg d$, the electric field becomes

$$\mathbf{E} = \frac{1}{4\pi\epsilon_0} \frac{2q}{z^2} \hat{\mathbf{z}} \quad (3)$$

which is what you would expect, since the system acts like a point charge of charge $2q$.

b) Repeat part (a), only this time make the right hand charge $-q$ instead of $+q$.

Now the z -components cancel and the x -components don't. Mathematically, this means replacing $\sin(\theta)$ with $\cos(\theta)$.

$$\mathbf{E} = \frac{1}{4\pi\epsilon_0} \frac{2q}{z^2 + (d/2)^2} \cos(\theta) \hat{\mathbf{x}} = \frac{1}{4\pi\epsilon_0} \frac{qd}{(z^2 + (d/2)^2)^{3/2}} \hat{\mathbf{x}} \quad \square \quad (4)$$

where the 2 has canceled out with the $d/2$ that comes from the cosine. If $z \gg d$, then from far away it looks like a dipole, and the field reduces to that of a dipole:

$$\mathbf{E} = \frac{1}{4\pi\epsilon_0} \frac{qd}{z^3} \hat{\mathbf{x}} \quad (5)$$

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Jin-Ying Zhang



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