Electricity and Magnetism
Continuous Charge Distributions
Faraday Cages

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Jan 17, 2018

Last time

- electric field of a dipole
- continuous distributions of charge

Warm Up Questions

Very far away from an electric dipole, the electric field decreases as with distance from the dipole r as:

(A) $\frac{1}{r}$

(B) $\frac{1}{r^2}$

(C) $\frac{1}{r^3}$

(D) $\frac{1}{r^4}$

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Warm Up Questions

Very far away from a uniform ring of charge, the electric field decreases as with distance from the dipole r as:

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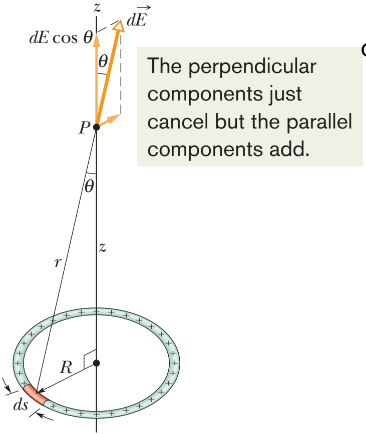
Overview

- more fields from continuous charge distributions
- conductors in fields

Example: Field from a ring of charge (23.8 in textbook)



Vertical components? From each charge $dq = \lambda\, ds$:

$$dE_z = dE\cos\theta$$

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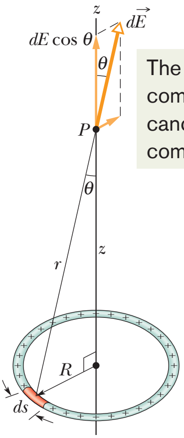

The perpendicular components just cancel but the parallel components add.

Vertical components? From each charge $dq = \lambda\, ds$:

$$\begin{aligned} dE_z &= dE\cos\theta \\ &= \left(\frac{k\lambda\, ds}{r^2}\right)\cos\theta \\ &= \left(\frac{k\lambda\, ds}{(R^2+z^2)}\right)\frac{z}{\sqrt{R^2+z^2}} \\ &= \frac{k\, z\, \lambda\, ds}{(R^2+z^2)^{3/2}} \end{aligned}$$

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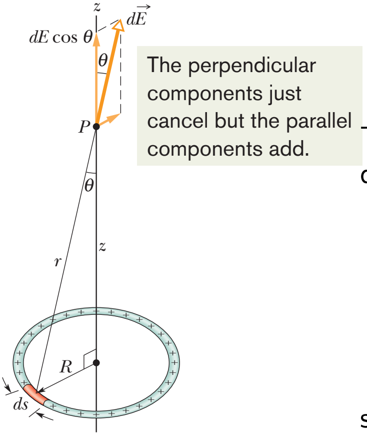


$$\mathrm{dE_z} = \frac{k\,z\,\lambda\,\mathrm{ds}}{(R^2+z^2)^{3/2}}$$

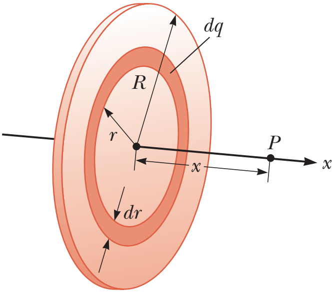
There are $2\pi R$-worth of little lengths ds. Adding the field for all together:

$$E_z = \int \mathrm{dE_z} = \frac{k\,z\,\lambda}{(R^2+z^2)^{3/2}} \int \mathrm{ds}$$

$$= \frac{k\,q\,z}{(R^2+z^2)^{3/2}}$$

since total charge $q = 2\pi R\lambda$ by definition.

Example: Field from a disk of charge (23.9 in textbook)

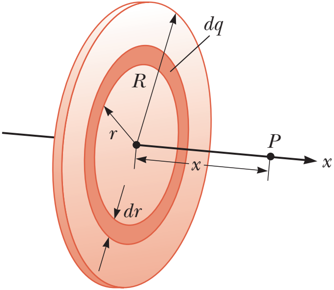


We already know the field contribution for a ring of charge. ($\mathrm{dq} = 2\pi r \sigma \, \mathrm{dr}$)

Just add up rings of different radius.

$$
\begin{aligned}
E_x &= \int_0^R \frac{k\,x}{(r^2 + x^2)^{3/2}} (2\pi r \sigma) \, \mathrm{dr} \\
&= 2\pi k \sigma \left[1 - \frac{x}{\sqrt{R^2 + x^2}} \right]
\end{aligned}
$$

Example: Field from a disk of charge (23.9 in textbook)



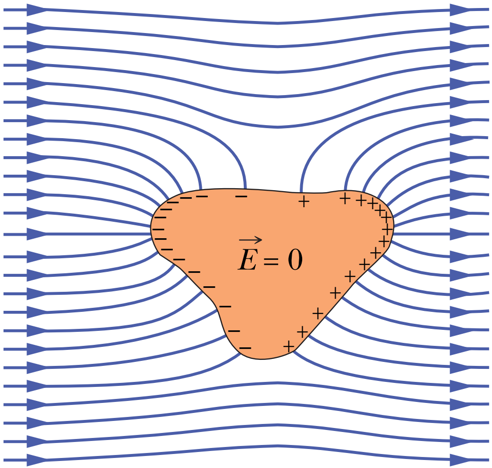
$$E_x = 2\pi k\sigma\left[1 - \frac{x}{\sqrt{R^2 + x^2}}\right]$$

What happens if $x \to \infty$ while R is constant?

What happens if $R \to \infty$ while x is constant?

Conductors in Electric fields

Consider a **neutral conductor** placed in an electric field:



Conductors in Electric fields

Electric fields exert forces on free charges in conductors.

Each charge keeps moving until:

1. the charges reaches the edge of the conductor and can move no further OR
2. the field is cancelled out!

Inside a conducting object, the electric field is zero!

Effects of E-Fields: Sparking (Electrical Breakdown)

Electric fields can cause forces on charges.

If the field is very strong, it begins to accelerate free electrons which strike atoms, knocking away more electrons forming ions. This starts a cascade, forming a spark.

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The air along the spark becomes a **plamsa** of free charges and can conduct electricity.

Sparks look like bright streaks because the air molecules becomes so hot. Accelerating charges radiate, so lightning can also cause radio interference.

Faraday Cages

A conducting shell can shield the interior from even very strong electric fields.

[1]Photo from Halliday, Resnick, Walker

Faraday Cages

[1]Photo found on TheDailySheeple, credits unknown.

Summary

- more continuous charge distributions
- conductors in electric fields

Quiz on Friday, Jan 19.

Homework

- Collected homework 1, posted online, due on Monday, Jan 22.

Serway & Jewett:

- PREVIOUS: Ch 23, Probs: 45, 71, 84
- NEW!: Ch 23, Probs: 75, 83