Arvind Borde / PHY 12, Week 1: Electric Charge and Electric Field

Introduction to Electricity

We become aware of something __________ in the state of physics simply by observing the behavior of the world around us.

We deduce that the phenomenon that we call gravitation exists, because ________________

1

Similarly, there are day-to-day phenomena that suggest that something, we call electricity, exists.
(1) What? ____________________.

We now know that electricity exists because of something called ___________________. It comes in two varieties, ___________ and ___________.

2

Conservation of Charge

Electric charge is conserved: ____

This means that the the total charge of an isolated system must stay the same. If new negative charge is produced, there must be an equal amount of positive electric charge produced.

3

(2) What other conservation laws do you know?
____

(3) Electric forces are quite strong, but we are only aware of them occasionally (as during a static attack). Why?

____

4

We now know that charges are built into the fundamental building blocks of matter, atoms:

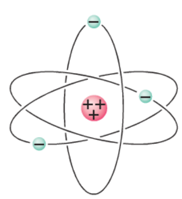

FIGURE 16–3 Simple model of the atom.

The nucleus of an atom has ______________; the electrons around it have _______________.

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Atoms can sometimes pick up extra electrons or lose a few. Charged atoms are called _____.

It is the loss or gain of *electrons* that leads to objects being positively (___) or negatively (___) charged.

6

ADDITIONAL NOTES

Like atoms, molecules (collections of bound atoms) are generally electrically neutral. But they can exhibit electrical behavior if the charges in them are asymmetrically placed.

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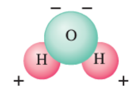
FIGURE 16–4 Diagram of a water molecule. Because it has opposite charges on different ends, it is called a "polar" molecule.



H_2O is called a ______________ molecule.

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Insulators and Conductors

(4) What do conductors conduct?

____

(5) What do insulators do?

____

9

Metals are good conductors; most other materials are insulators.

(6) Have you heard a word in connection with computers or electronics that suggests something in-between the two?

____

(7) Example? ________________

10

Electrons in an insulating material are bound tightly to the nuclei.

Some electrons in a conductor are bound loosely and can move freely within it.

They are called ______________________, or ______________.

In a semiconductor, there are fewer free electrons.

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Induced Charge

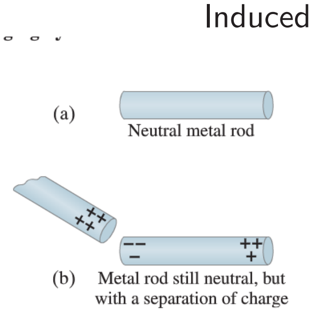

FIGURE 16–7 Charging by induction: if the rod in (b) is cut into two parts, each part will have a net charge.

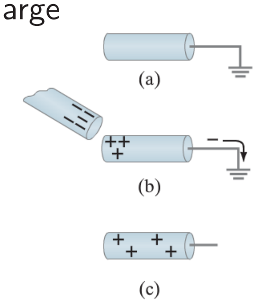

FIGURE 16–8 Inducing a charge on an object connected to ground.

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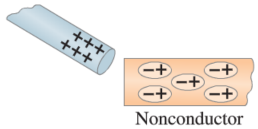
ADDITIONAL NOTES

FIGURE 16–9 A charged object brought near a nonconductor causes a charge separation within the nonconductor's molecules.



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Coulomb's Law

$$F_{\text{elec}} = k\frac{q_1 q_2}{d^2},$$

$$k \approx 9 \times 10^9 N \cdot m^2/C^2$$

Coulomb constant

Charge is measured in units called ________, in the system we use. In these units an electron has a charge of

14 $e \approx 1.6 \times 10^{-19}$C.

Coulomb's law tells you that the electrical force between two objects with charges q_1 and q_2 is attractive or repulsive and points in the direction of the straight line between them.

$q_1(+)\bullet\underbrace{\rightarrow\text{attractive electrostatic force}\leftarrow}_{\text{distance } = d}\circ q_2(-)$

$q_1(+)\bullet\underbrace{\leftarrow\text{repulsive electrostatic force}\rightarrow}_{\text{distance } = d}\bullet q_2(+)$

$q_1(-)\circ\underbrace{\leftarrow\text{repulsive electrostatic force}\rightarrow}_{\text{distance } = d}\circ q_2(-)$

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(**8**) Is it possible for day-to-day object to have a charge of 0.8×10^{-19}C?

____

____

NOTE: Charges are often expressed as millionths of a Coulomb, ____________

16

(**9**) if an object has a charge of 16 C, how many electrons has it gained or lost?

____

____

(**10**) If $m_e = 9.1 \times 10^{-31}$ kg what is the mass change?

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(**11**) What is the electrical force between a charge of $.5\,\mu$C and one of -2.1 C that are a distance of 10 cm from each other?

$F =$

18

ADDITIONAL NOTES

(**12**) What is the electrical force between a charge of $-2.3\,\text{mC}$ and one of $-4.1\,\text{mC}$ that are a distance of $1\,\text{km}$ from each other?

$F =$

19

(**13**) How does a charge "transmit" its electrical influence to another?

____

____

____

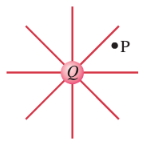
____

20

Electric forces (in fact, all fundamental forces) are transmitted via an **electric field**.

This is an abstract concept. (So is energy, but we get used to it.)

FIGURE 16–22 An electric field surrounds every charge. The red lines indicate the electric field extending out from charge Q, and P is an arbitrary point.



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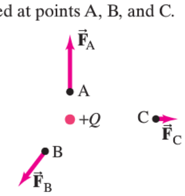
This is how the electric force created by a $+$ charge Q is "felt" by a small positive test charge q:

FIGURE 16–23 Force exerted by charge $+Q$ on a small test charge, q, placed at points A, B, and C.



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(**14**) What is the law that determines electric force between Q and q?

The electric field is defined as $\vec{E} = \dfrac{\vec{F}_{\text{elec}}}{q}$ as $q \to 0$.

So the field created by the charge Q is

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(**15**) What (in SI) are the units of $\vec{E}$?

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ADDITIONAL NOTES

The electric force on a test charge q depends on the charge.

The electric field at a point depends only on the charge creating the field.

You can represent electric fields as you do forces.

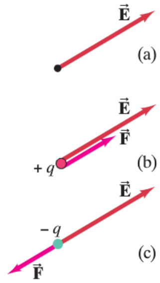

FIGURE 16–24 (a) Electric field at a given point in space. (b) Force on a positive charge at that point. (c) Force on a negative charge at that point.

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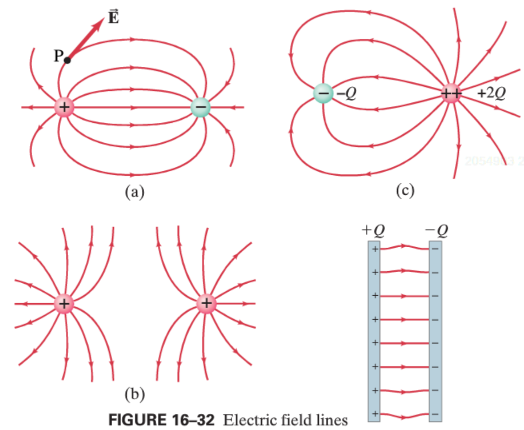

FIGURE 16–32 Electric field lines for four arrangements of charges.

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Conventions for electric field lines

- ______________________________; field points in direction tangent to line at a point.
- ______________________________ ______________________________. The closer the lines, the stronger the field.
- ______________________________.

27

(16) Calculate the electric field at a point P that's $90\,\text{cm}$ to the right of a point charge $Q = -9 \times 10^{-6}$ C.

$$\vec{E} =$$

28

Electrical fields and conductors

The electric field inside a conductor is zero in the static situation (charges at rest).

(17) Why?

____

____

____

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So, charge on a conductor distributes itself on the surface.

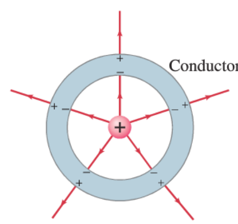

FIGURE 16–34 A charge inside a neutral spherical metal shell induces charge on its surfaces. The electric field exists even beyond the shell, but not within the conductor itself.

Also the electric field is perpendicular to the surface of the conductor.

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ADDITIONAL NOTES

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