Electricity Lecture Series

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Charges & Charging

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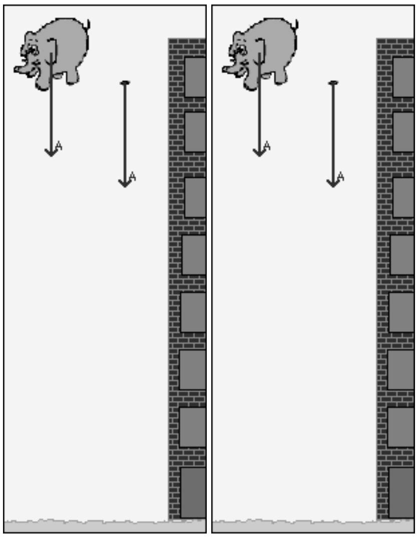
Electric Charges

At the end of this unit, you will be able to:

1. *Explain the gravitational forces acting on any object.*
2. *Mathematically represent the gravitational force and describe its impact on physical events.*
3. *Describe existence of electrical charges in matter its magnitude, mass and its quantization property.*
4. *Sketch and explain the charging by induction and charging by contact numerically and diagrammatically.*

GRAVITATIONAL FORCES

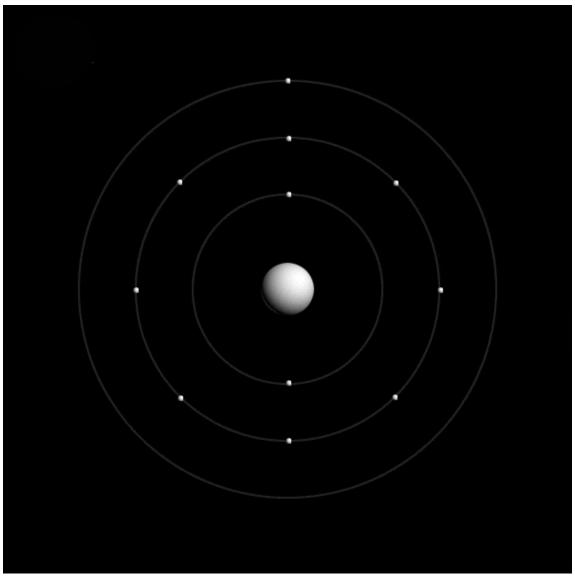


Galileo Science: All objects regardless of size, shape or mass will fall at the same rate

Newton extended the principle: Universal Gravitational Law: All object will attract each other with force inversely proportional to square of distance

$$\vec{F}_{21} \propto \frac{m_2 m_1}{r^2} \qquad \vec{F}_{21} = G\frac{m_2 m_1}{r^2}$$

ATOMIC STRUCTURE



Electric Charges

Matter: made up of atoms and molecules

Atom: made up of nucleus, protons and electrons

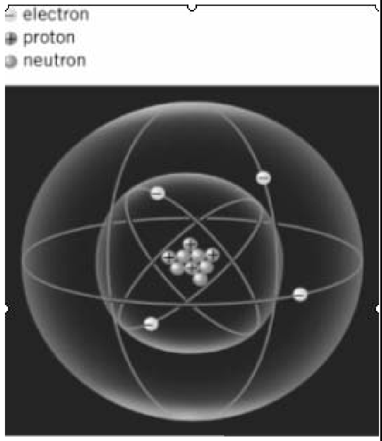
Charged object: imbalance number of electrons & protons

Positively charged

Negatively charged

Conductors: charges can move freely

Insulators: charges cannot move freely



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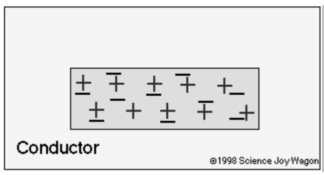
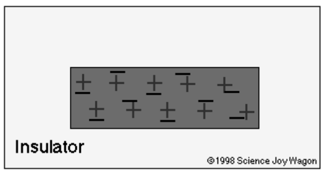




18.1 The Origin of Electricity
Cutnell & Johnson 7E

The electrical nature of matter is inherent in atomic structure.

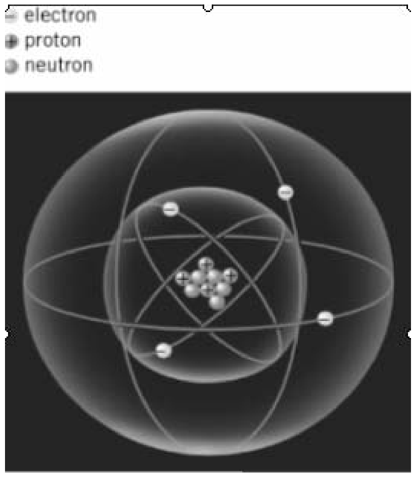
$$m_p = 1.673 \times 10^{-27}\,\text{kg}$$

$$m_n = 1.675 \times 10^{-27}\,\text{kg}$$

$$m_e = 9.11 \times 10^{-31}\,\text{kg}$$

$$e = 1.60 \times 10^{-19}\,\text{C}$$

coulombs

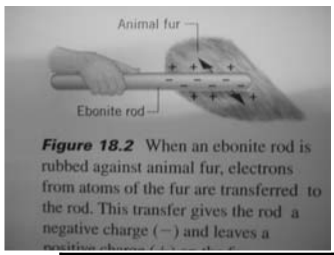


Electric Charges

Charge quantization: charges exist in multiples of an elementary charge, the charge of an electron

$$q = Ne = e, 2e, ..$$

where N are the number of electrons & the elementary charge e is
e =1.6 x 10^{-19} C
Number of charges in 1 C??
N=q/e =1 C/1.6 x 10^{-19} C
N = 6.25 x 10^{18}



N	Q (x10^{-19} C)
1	1.6=e
2	3.2=2e
5	80=5e
10	16=10e

Charges, charging, electrical force & discharging

Matter	Neutral
Conductor	Charged
Insulator	Discharged
Atom	Conduction
Charges	Induction
Electron	Friction
Proton	Contact
Positive	Ground
Negative	Lightning
Attract	Force
Repel	distance

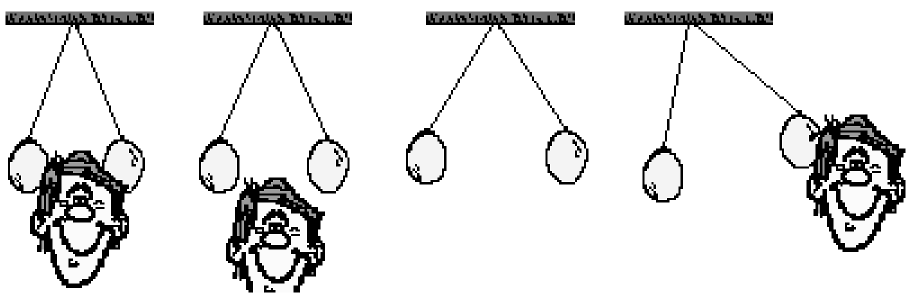
Highest electron affinity →

Triboelectric Series

Celluloid
Sulfur
Rubber
Copper, Brass
Amber
Wood
Cotton
Human Skin
Silk
Cat Fur
Wool
Glass
Rabbit Fur
Asbestos

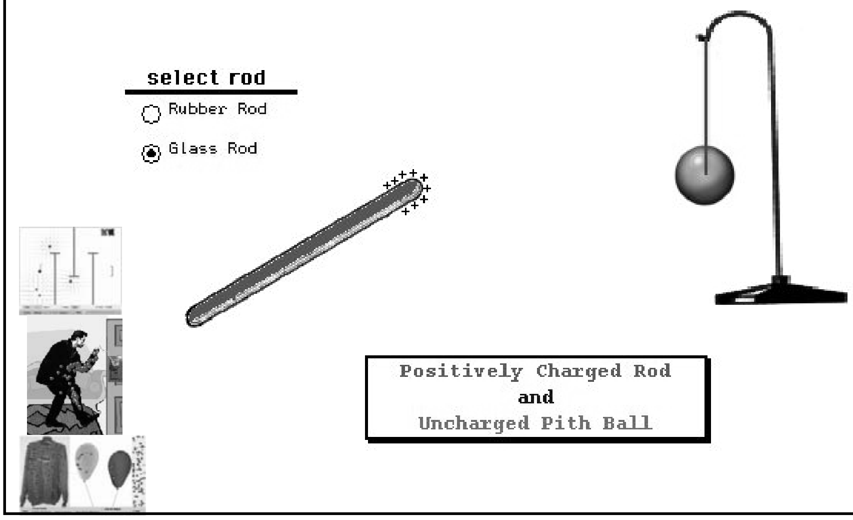
Rubbing wool to rubber caused rubber to have excess electrons which were transferred from rubber

Charging by Friction



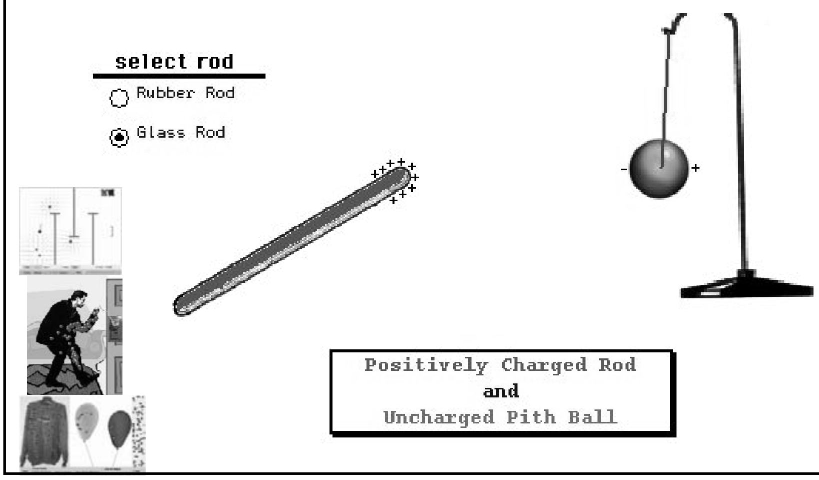
Two balloons rubbed on human hair will become negatively-charged and have an attractive interaction with the hair. If the hair is removed, the balloons repel.

Charges, charging, electrical force & discharging



Charging by contact

Bringing the rod near the pithball causes polarization (separation of charges)



Charging by contact

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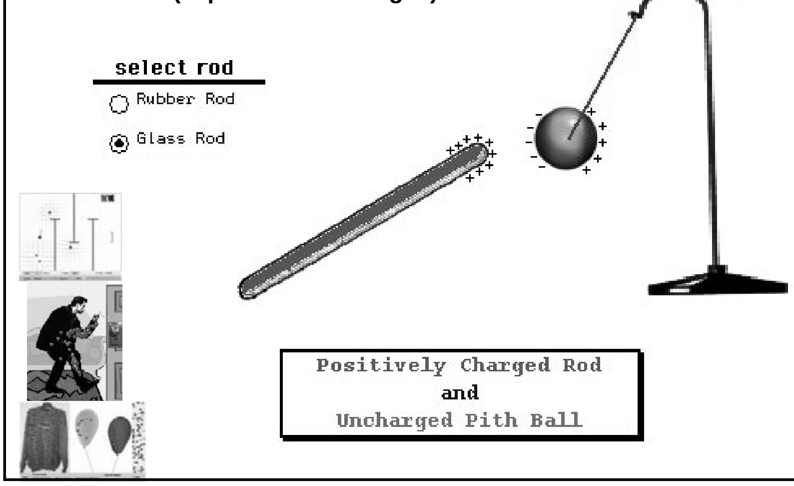
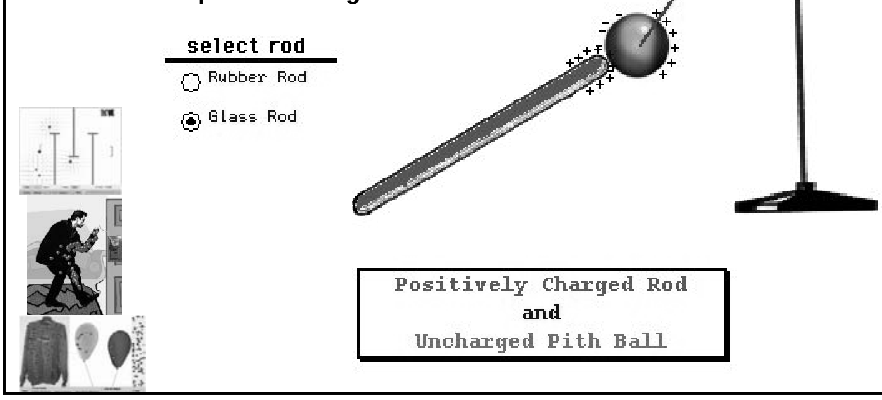


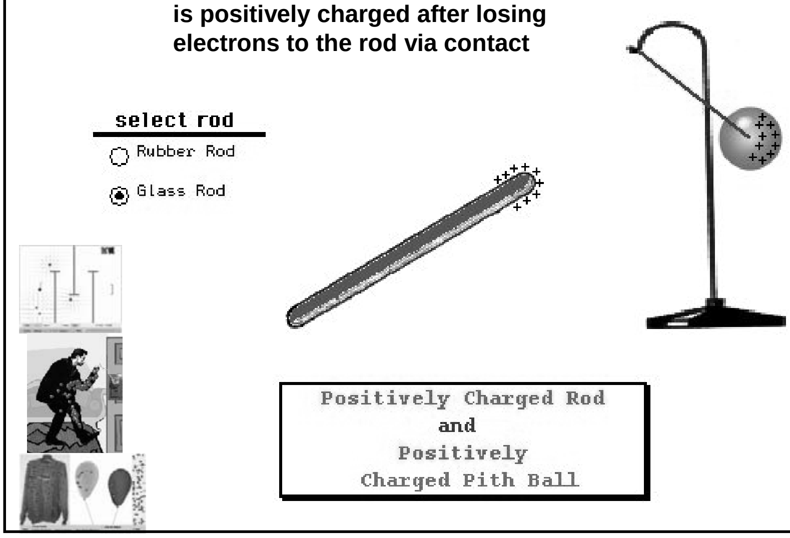
Charging by contact

Bringing the rod near the pithball causes polarization (separation of charges). Touching the rod will allow electrons to "flow" to the rod. The rod remains positively charged since the number of electrons transferred is far too small to neutralize the positive charges



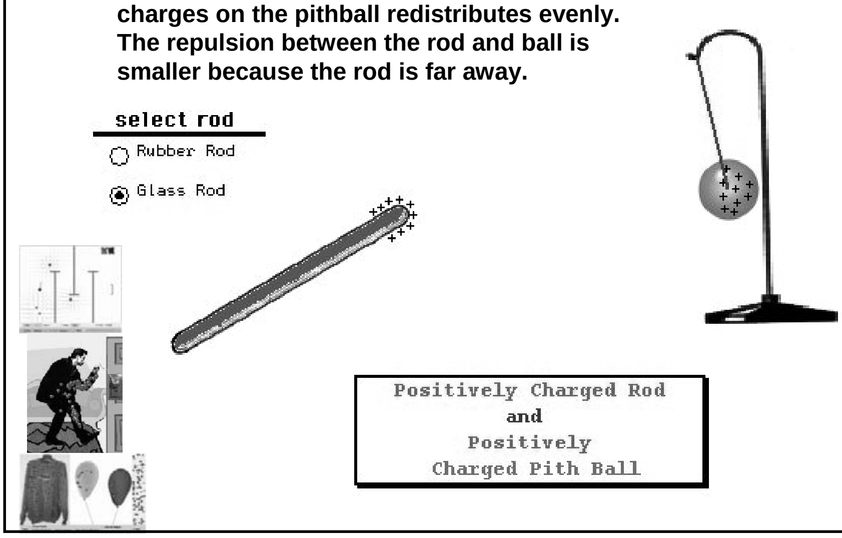
Charging by contact

The pithball is now repelled since it is positively charged after losing electrons to the rod via contact



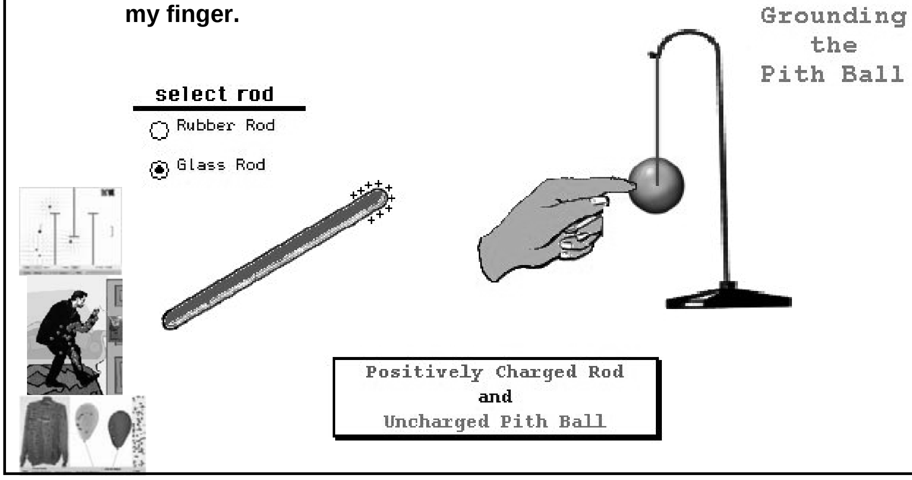
Charging by contact

When the rod is pulled further away, the charges on the pithball redistributes evenly. The repulsion between the rod and ball is smaller because the rod is far away.



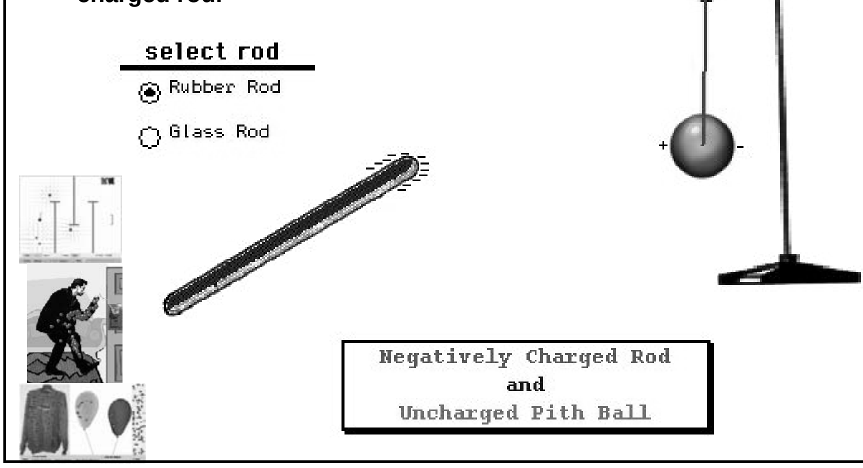
Charging by contact

The pithball is now neutralized by grounding (pathway to transfer electrons to the positively charged pithball) it with my finger.



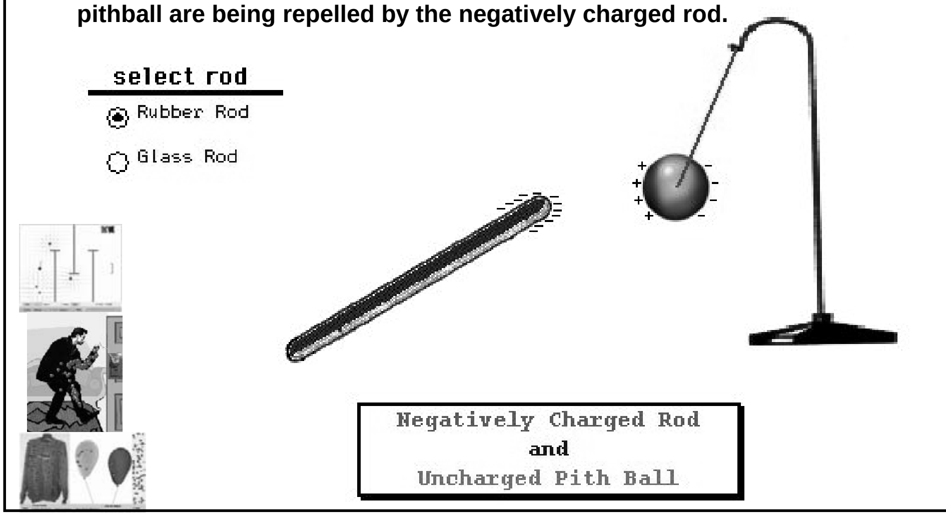
Charging by contact

Pithball is polarized (separation of charges) when the rod is brought nearer. The electron on the pithball is being repelled by the negatively charged rod.



Charging by contact

Pithball is polarized (separation of charges) even more when the rod is brought nearer. The electrons on the pithball are being repelled by the negatively charged rod.



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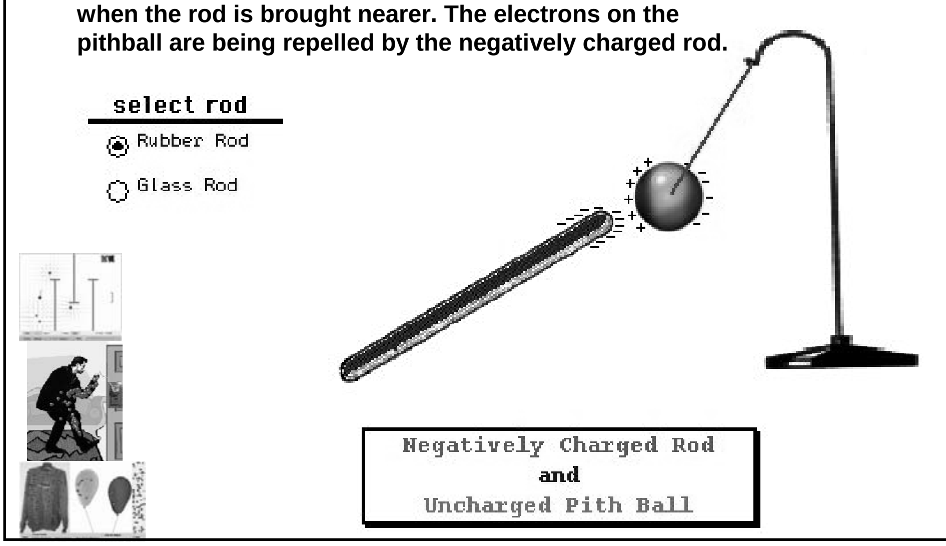
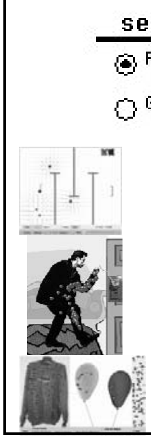
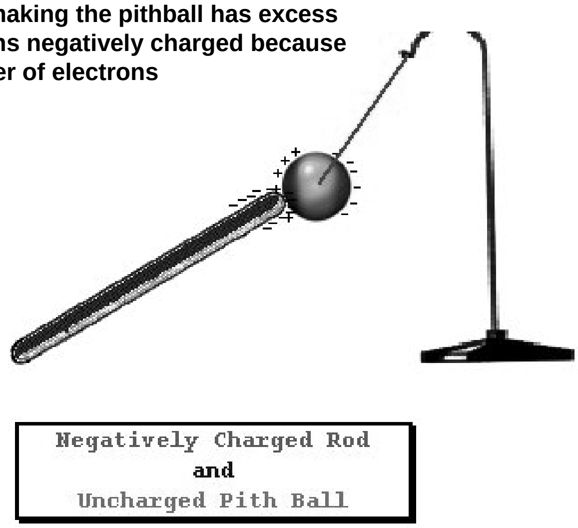


Charging by contact

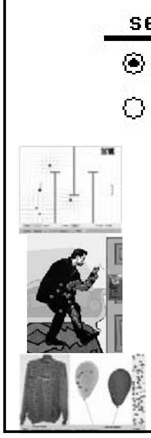
Electrons move from the rod to the side of the pithball which is being touched making the pithball has excess electrons. The rod remains negatively charged because it only lost a small number of electrons

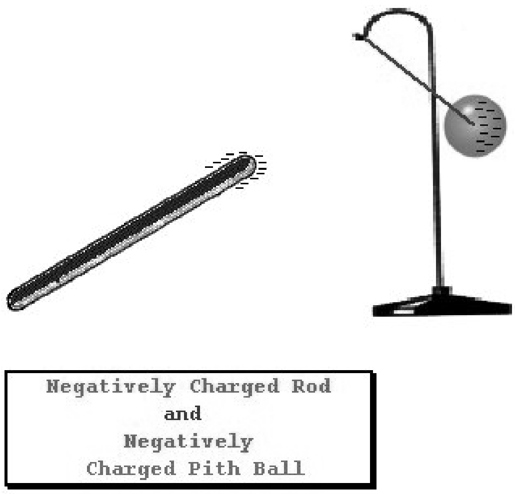




Charging by contact

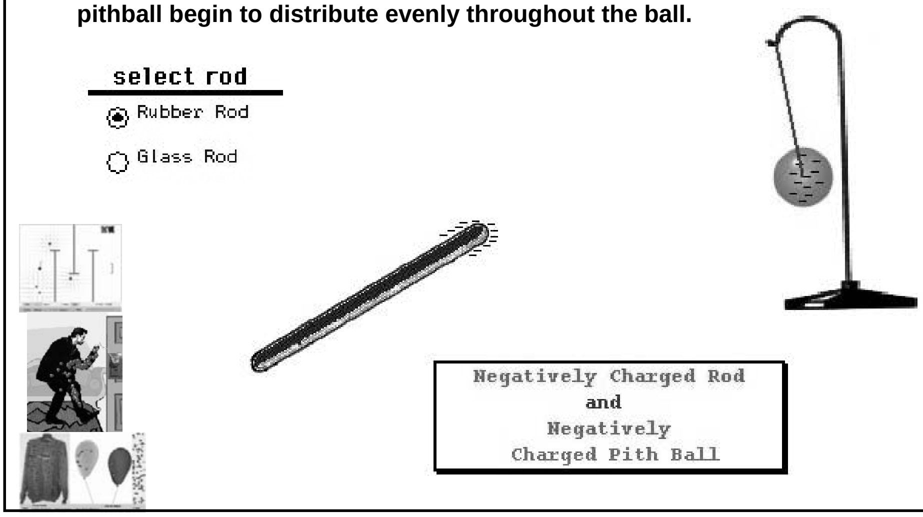
Since the rod and the pithball are both negatively charged, the pithball is being repelled strongly.





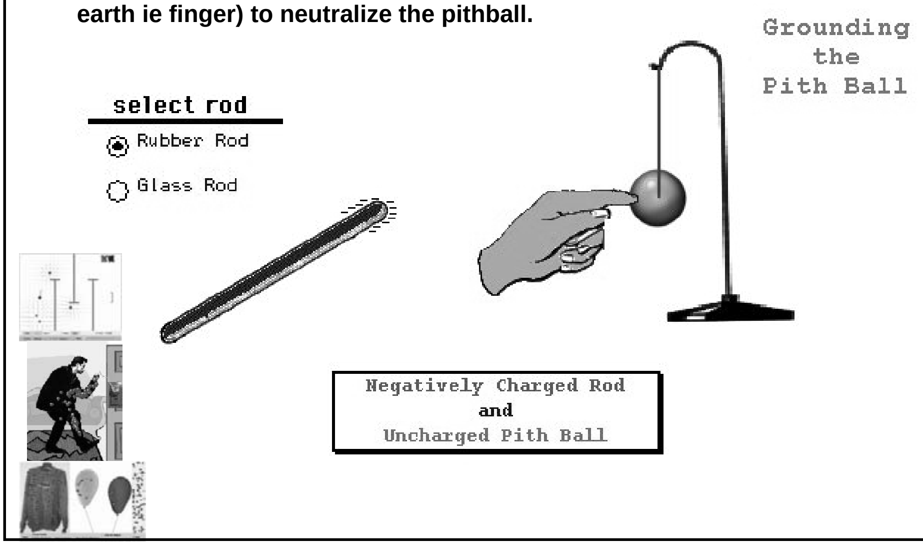
Charging by contact

The repulsion is getting smaller when the rod I pulled farther away. At the same time, the electrons on the pithball begin to distribute evenly throughout the ball.

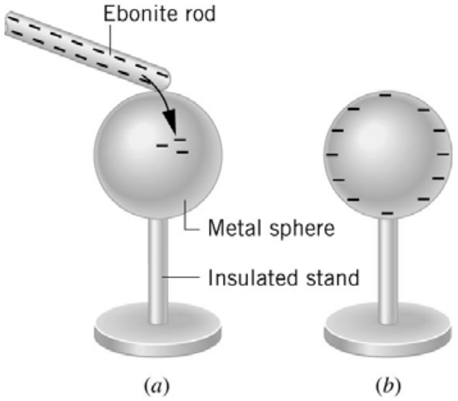


Charging by contact

The ball is being grounded (leaking off the electrons to earth ie finger) to neutralize the pithball.



18.4 Charging by Contact
Cutnell & Johnson 7E



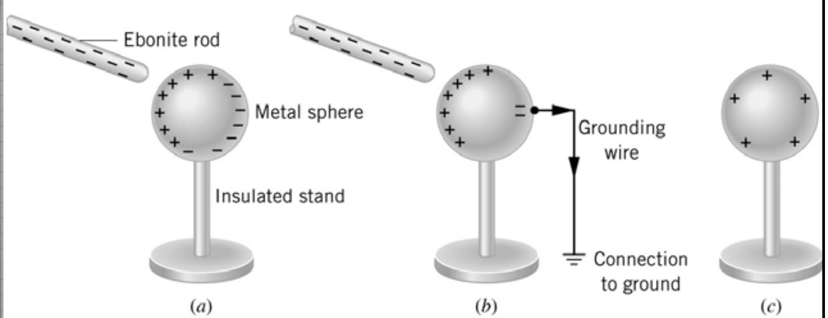
Electrons are transferred to the neutral conducting sphere when the sphere is touched by the negatively charged rod.

Charging by contact.

18.4 Charging by Induction
Cutnell & Johnson 7E

Charging by induction is a 3-stage process:

1. **Bring a charged rod near the sphere to cause polarization of the charges**

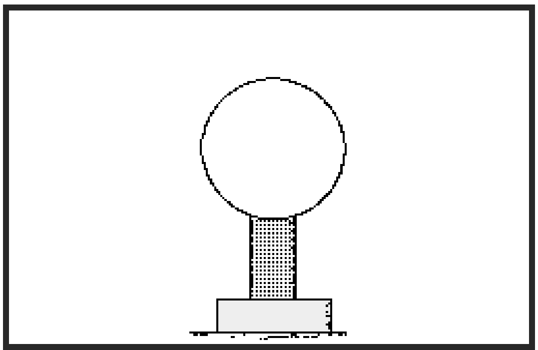


Charging by induction.

2. **Ground the side of the sphere which is furthest from the charging source.**
3. **Remove the charging source**

Charging by Induction:

1. Bring negatively charged rod near the sphere
2. Ground the sphere to remove the electrons
3. Sphere is positively charged

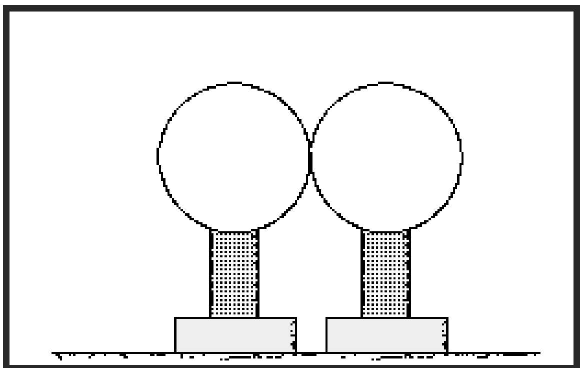


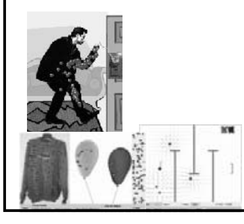
A negatively charged object is brought near to a neutral, conducting sphere. Electrons in the sphere are forced from the left side of the sphere to the right side.

Animation source from: “The Multimedia Physics Studio” website and The PhET website

Charging by Induction: Two Neutral conducting spheres

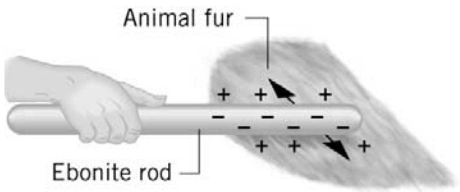
1. Bring negatively charged balloons near the sphere
2. Pull the second sphere after electrons have migrated to the second sphere.
3. Sphere 1 is positively charged and sphere 2 is negatively charged





Two neutral conducting spheres are touching one another, thus allowing for the free movement of electrons between them.

18.2 Charged Objects and the Electric Force
Cutnell & Johnson 7E



LAW OF CONSERVATION OF ELECTRIC CHARGE

During any process, the net electric charge of an isolated system remains constant (is conserved). Total number of negative charges (electrons) and positive charges (protons) must be equal

Consider the fur and rod together as a system. Since the system is uncharged initially, then the total charge must be zero before and after rubbing. Hence if rod acquires 6e due to rubbing (friction), then the fur must have lost 6e, the total charge for the fur-rod is zero.

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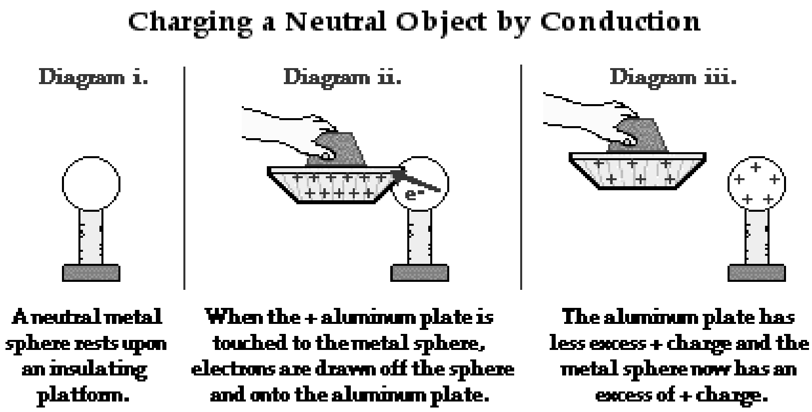
Cutnell & Johnson 7E



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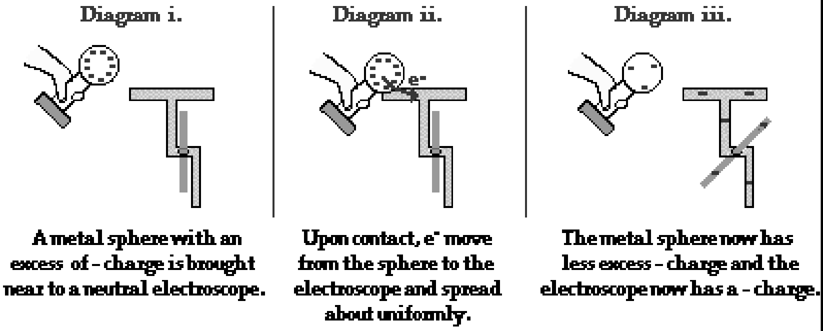
Cutnell & Johnson 7E

Charging a Neutral Object by Conduction



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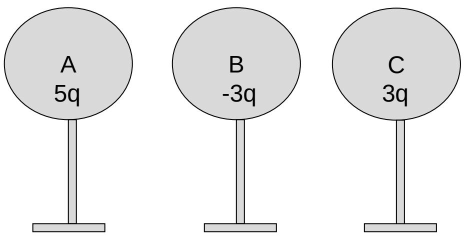
Charge Conservation

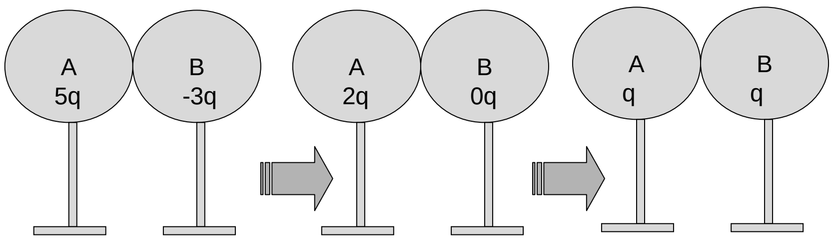
Shown are conducting spheres each of charges 5q, -3q and 5q

What is the total charge on the spheres?

Sphere A touches sphere B and then separated.

What is the total charge after the process above, the charge on each individual sphere?





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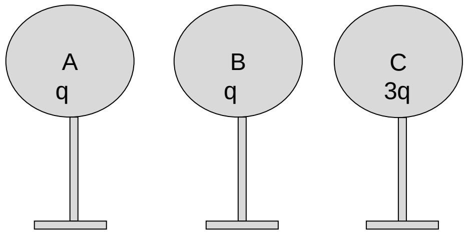

Sphere B touches sphere C and then separated.

What is the total charge after the process above, the charge on each individual sphere?