# Physics 142 - Sept. 4, 2007

recall what you know about the most obvious force of nature → gravitation

$$|\vec{F}| = \frac{G m_1 m_2}{r^2}$$

$6.67 \times 10^{-11} \ \frac{N \cdot m^2}{kg^2}$


one "charge"
↳ mass

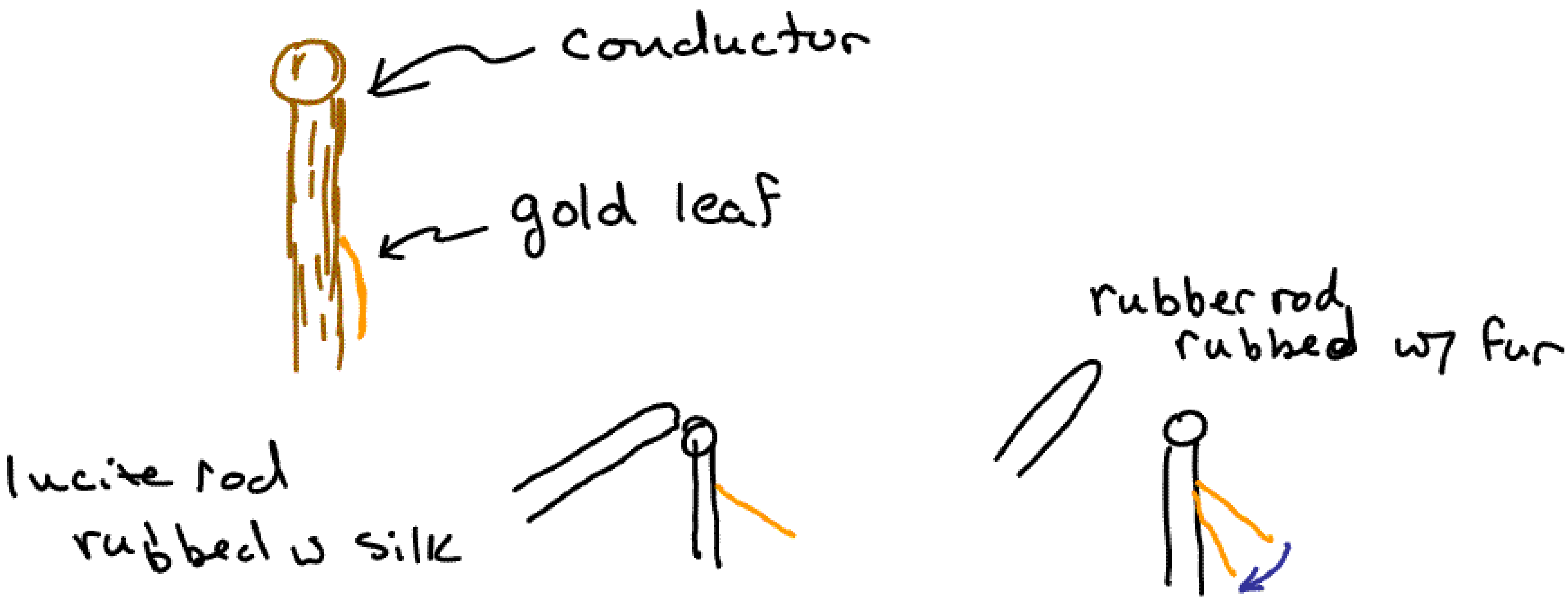
$\hat{r}$ = unit vector along $\vec{r}$

$$\vec{F} = -\frac{G m_1 m_2}{\vec{r}^{\,2}} \hat{r}$$

Force is only attractive

"–" sign
↳ attractive force

# Electric charge + Electroscopes

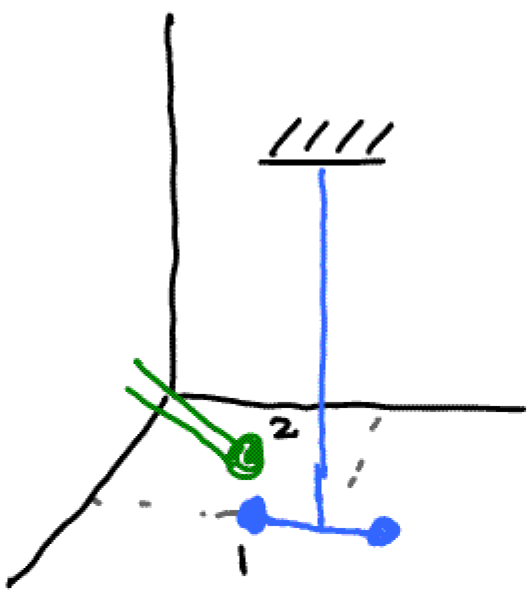



Vice versa we start w/ other rod

Electric charge

Two types — like types repel / unlike types attract

Charles Augustin Coulomb 1785 (1736–1806)



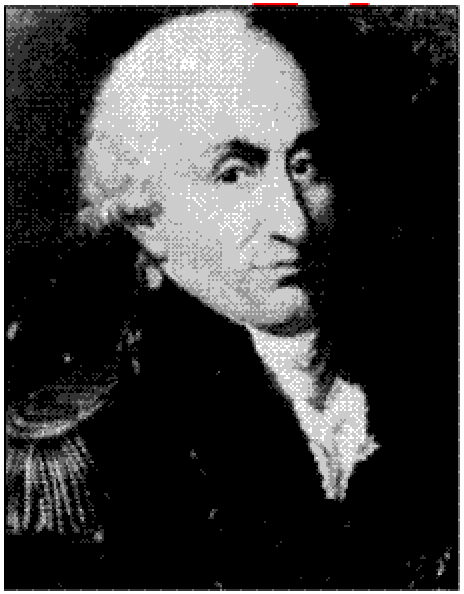

Torsion balance

Studied force as fn of charge + distance

$$F \propto \frac{q_1 q_2}{r^2}$$

Coulomb's law

# Electric force



Charles Coulomb

(1736 - 1806)

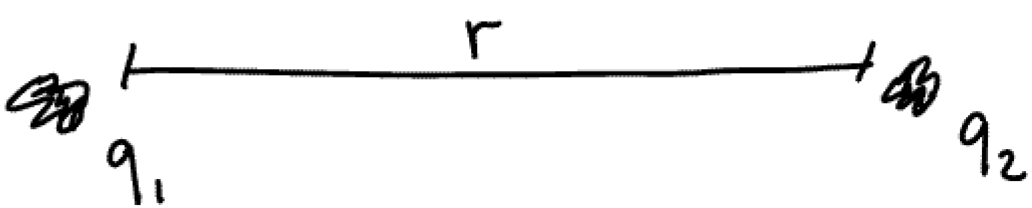
French military engineer

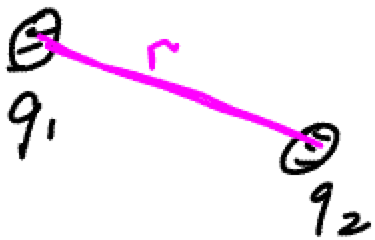
$\Rightarrow$ Coulomb's Law

$$F_{\text{electric force}} = \frac{k\, q_1 q_2}{r^2}$$

$q \equiv$ electric charge

$q_{1,2} = \pm \#$






$$\vec{F}_{12} = \frac{k\, q_1 q_2}{r^2}\,\hat{r}$$

Force of $q_1$ on $q_2$

Vector

$\hat{r}$ unit vector along $\vec{r}$

k constant : sets the scale

$$= \frac{1}{4\pi\epsilon_0} \qquad \vec{F} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\,\hat{r}$$

$$8.99 \times 10^{9}\ \frac{N\,m^2}{c^2}$$

MKS units

F in Newtons

r in m

q in Coulomb

$$\epsilon_0 = 8.85 \times 10^{-12}\ \frac{c^2}{N\,m^2}$$

→ Permittivity of free space

electric charge is conserved

electric charge is quantized

$\pm |e| = 1.6 \times 10^{-19}$ Coulombs

$|q| = 2/3$

$= 1/3$ } quarks

# H atom

# Bohr Atom


$e^-$ moves in a circle abt the proton
Proton is stationary

$Q = 1.6 \times 10^{-19}$ Coulombs
$= +1|e|$ C

$Q = -1.6 \times 10^{-19}$ C
$-1|e|$

Charge is quantized

$1.6 \times 10^{-19}$ C $\equiv e$
$|e|$

Only integral charge (multiples of $|e|$) found in Nature.

Quarks — which are constituents of particles like Protons — have fractional charge but are not seen in Nature because they are confined by the Strong Nuclear force.


How does $F_{em}$ compare to $F_{gravity}$?

$F_{em}$: Electrostatic

Proton: $1.6\times10^{-19}\,C$

$m_p = 1.67\times10^{-27}\,kg$

$m_e = 9.11\times10^{-31}\,kg$

$r_0 \equiv$ Bohr radius $= 5.29\times10^{-11}\,m$

$$F_{em} = \frac{k q_1 q_2}{r^2} = \frac{8.99\times10^{9}\,\frac{Nm^2}{C^2}\left(1.6\times10^{-19}\,C\right)^2}{\left(5.29\times10^{-11}\,m\right)^2}$$

$$F_{em} = 8.2\times10^{-8}\,N$$

$$|F_{grav}| = \left| -\frac{G m_p m_e}{r^2} \right| = 3.6 \times 10^{-47} N$$

$$\frac{F_{em}}{F_{grav}} = 2.3 \times 10^{39}$$

(b) what is the speed of $e^-$ ?

$$F_{centripetal} = F_{em} = \frac{m_e V_e^2}{r_o}$$

$V_e = 2.2 \times 10^6$ m/s $\sim$ 1% speed of light