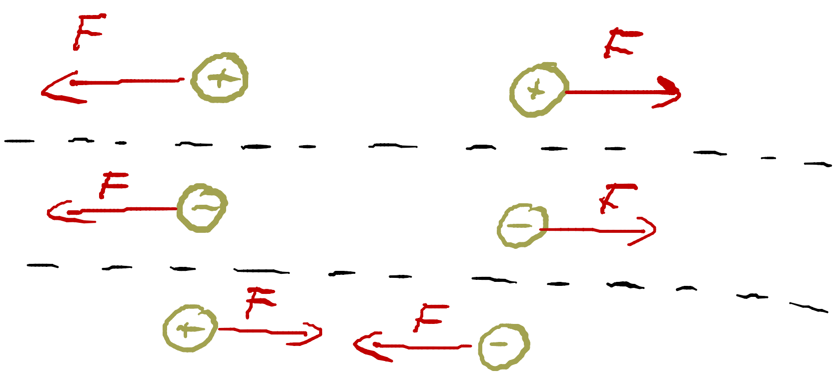
Recap

- electric charge q:
  - determines strength of electric force
  - can be positive or negative
  - is conserved and quantized
  - elementary charge: $e = 1.6 \cdot 10^{-19}\,C$
- electric force:
  - Like charges repel
  - Unlike charges attract

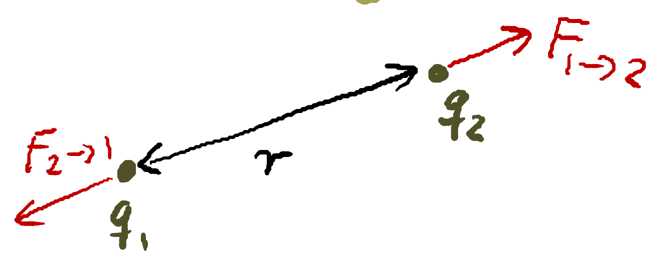


  - Coulomb's Law:

$$|F_{1\to2}| = |F_{2\to1}| = k\,\frac{|q_1|\cdot|q_2|}{r^2}$$

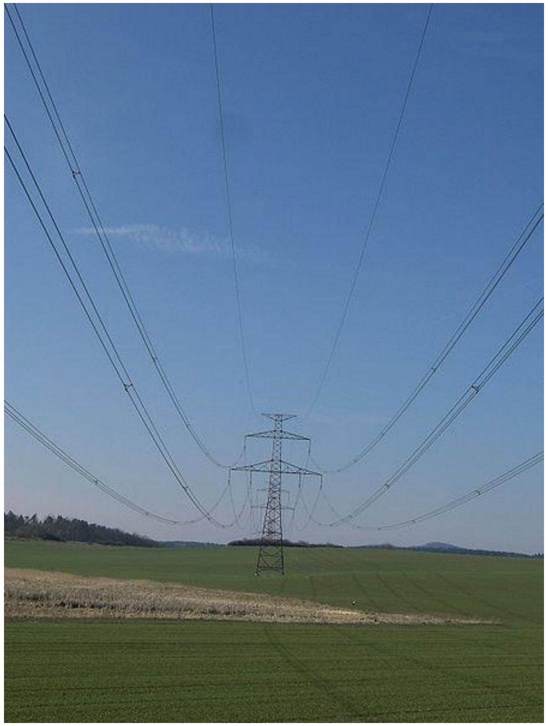
N III

electrostatic constant $k = 9.0 \cdot 10^{9}\ Nm^2/C^2$



Today:

- More on Coulomb’s law
- Conductors and insulators
- E-paper and copy machines



Quelle: Deutsche Fotothek

A **hydrogen atom** is composed of a nucleus containing a single **positive proton**, about which a single **negative electron** orbits. **The electric force between the two particles is 2.3x10^{39} times greater than the gravitational force!**

If we can adjust the distance between the two particles, can we can find a separation at which the electric and gravitational forces are equal?

$$F_{grav} \propto \frac{1}{r^2}$$

$$F_{electr} \propto \frac{1}{r^2}$$

$$\frac{F_{el.}}{F_{grav}} = 2 \cdot 10^{39} \text{ indep. of } r$$

A. Yes, we must move the particles farther apart
B. Yes, we must move the particles closer together
C. No, at any distance

Note:

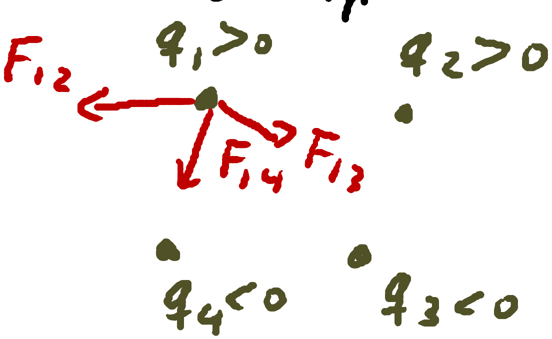
① Both F_{grav} and $F_{electric}$ scale with distance as $1/r^2$

② $$K = \frac{1}{4\pi\varepsilon_0} = 8.99 \cdot 10^9 \frac{Nm^2}{C^2}$$

with $\varepsilon_0 = 8.85 \cdot 10^{-12} \frac{C^2}{Nm^2}$ } permittivity of free space

③ Electrostatic force obeys the principle of superposition:

Example:



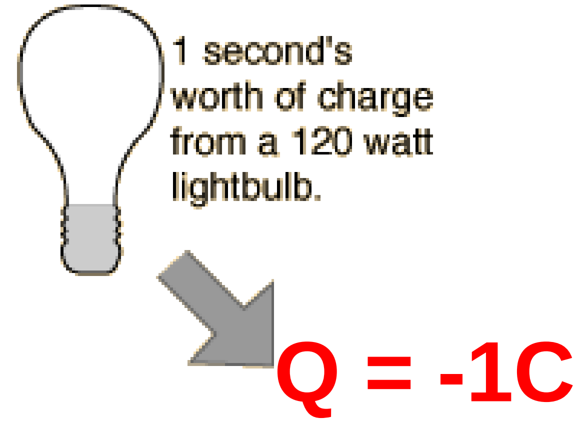
force on charge 1 from all other charge:

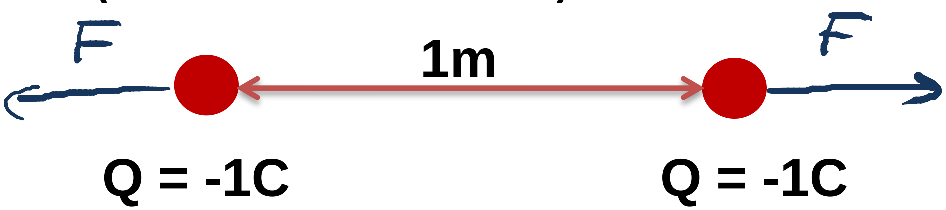
$$\vec{F}_{\text{on 1 by others}} = \vec{F}_{1,\text{net}} = \vec{F}_{\text{on 1 by 2}} + \vec{F}_{\text{on 1 by 3}} + \vec{F}_{\text{on 1 by 4}} + \ldots$$

add vectors!

Roughly, what is the magnitude of the electric force acting on each of two -1C point charges separated by a distance of 1 m?

(1 N = 0.225 lb.)





$$|F| = k\frac{|q_1|\cdot|q_2|}{r^2}$$

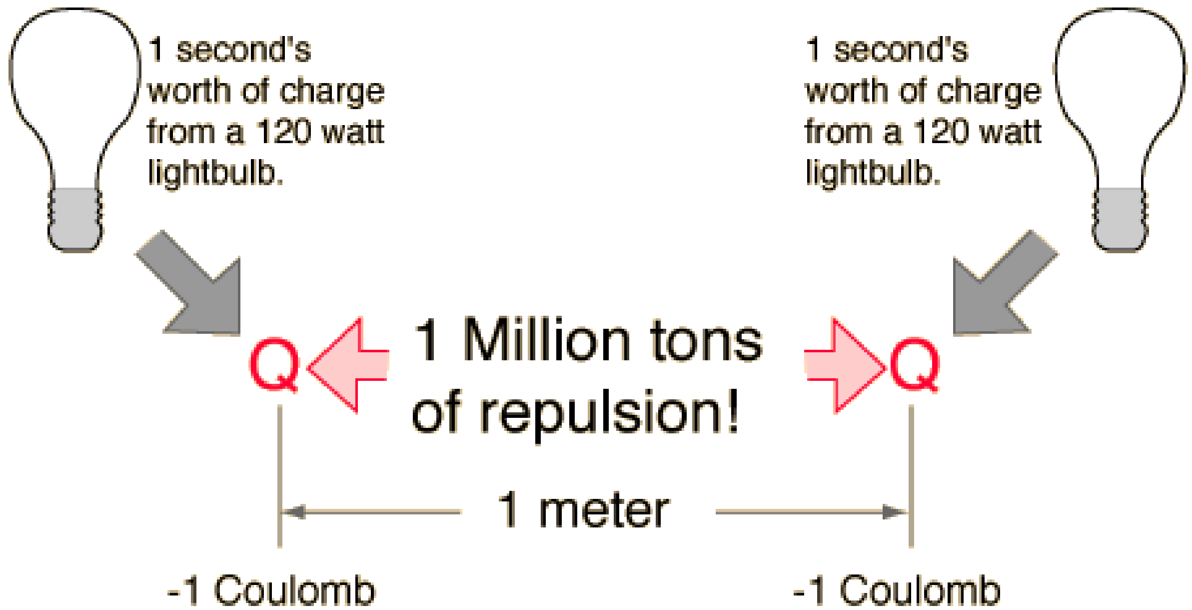
$$= 9\cdot 10^9 \frac{Nm^2}{C^2}\cdot\frac{1C\cdot 1C}{1m^2}$$

$$= 9\cdot 10^9 N \approx 10^9 kg\cdot g$$

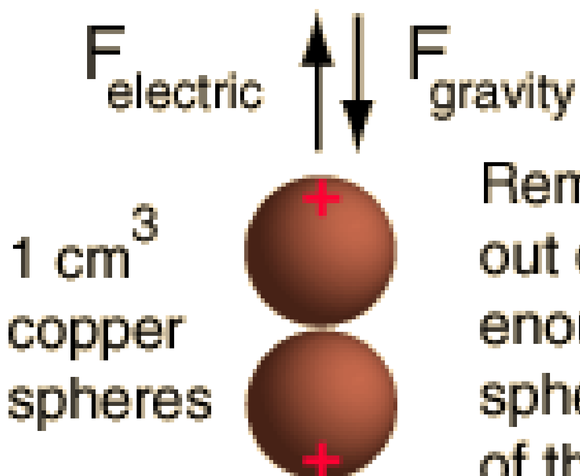
$$= \underline{10^6\cdot 1ton\cdot g}$$

F = ?

A. Much less than a pound.
B. 1 pound.
C. 1000 pounds.
D. 1000 tons.
E. 1 million tons.

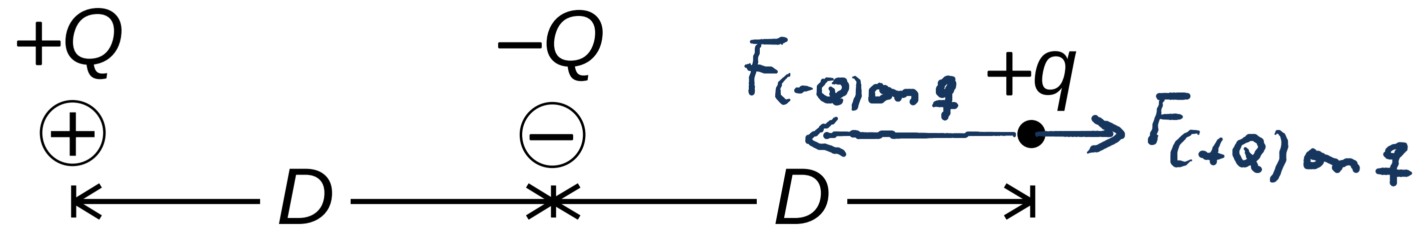


⇒ net charge of most objects ≈ 0 (+ and − charges cancel out mostly), or would generate large forces



Removal of one valence electron out of 5.7×10^{12} would provide enough net charge to lift the top sphere, overcoming the gravity of the entire Earth.

What is the **direction** of the **net electric force** acting on the particle with charge $+q$?



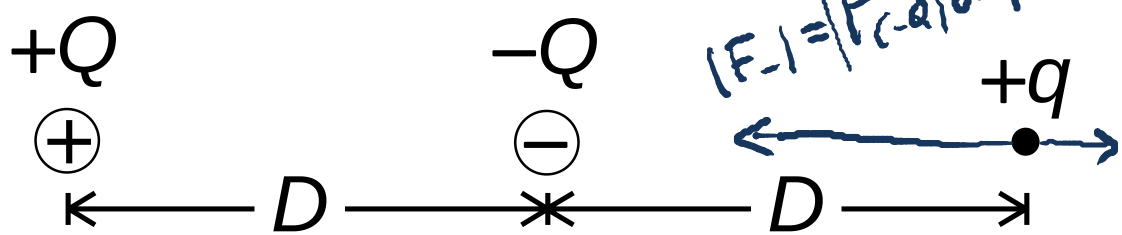
$F_{el} \propto \frac{1}{r^2}$

as $r \uparrow \Rightarrow |F| \downarrow$

A. →.	B. ←.
~~C.~~ ↑.	~~D.~~ ↓.
~~E.~~ No net force.	

If F_- is the magnitude of the electric force acting on $+q$ due to $-Q$, then what is the **magnitude of the <u>net</u> electric force** acting on $+q$**?**

$|F_-| = |F_{(-Q)\,on\,q}| = k\dfrac{Qq}{D^2}$

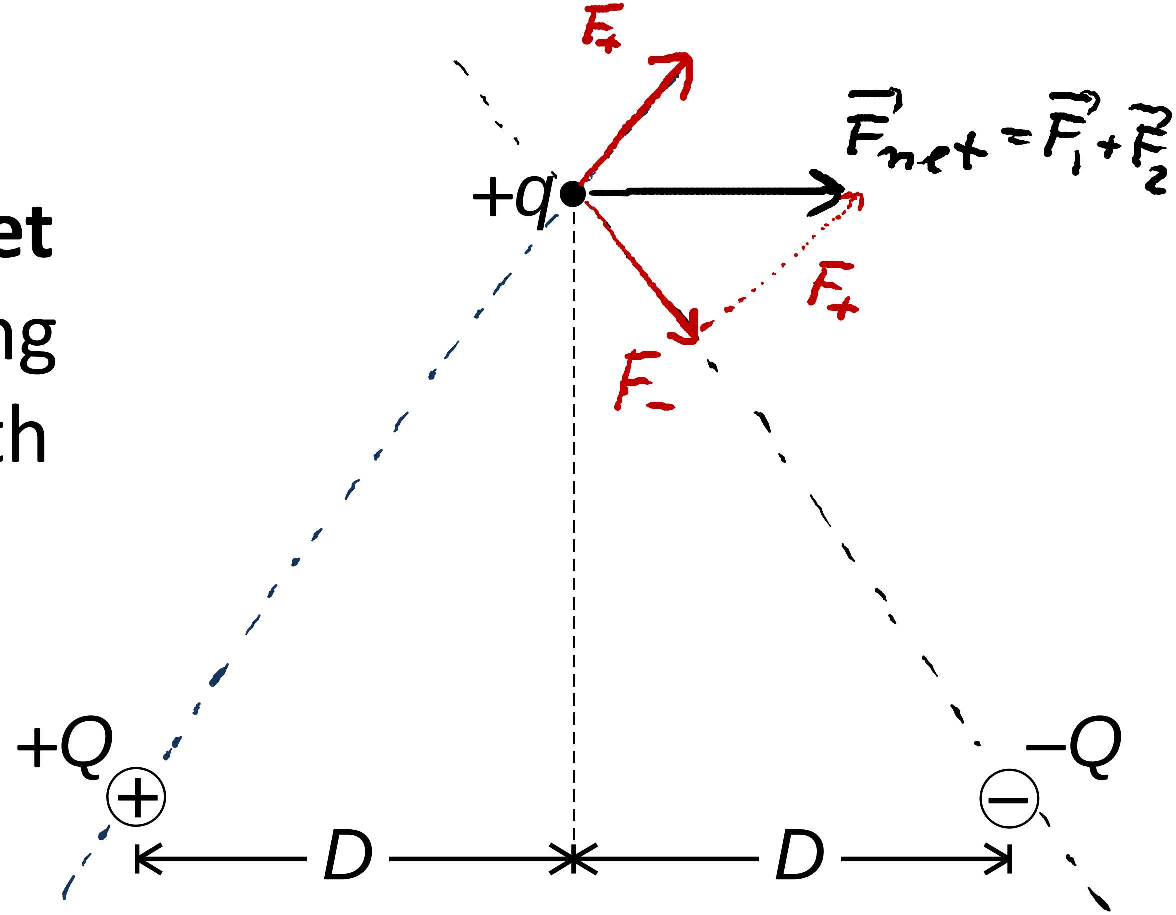


$|F_+| = k\dfrac{Qq}{4D^2} = \dfrac{1}{4}|F_-|$

$\Rightarrow F_{net} = |F_-| - |F_+| = |F_-| - |\tfrac{1}{4}F_-| = \dfrac{3}{4}|F_-|$

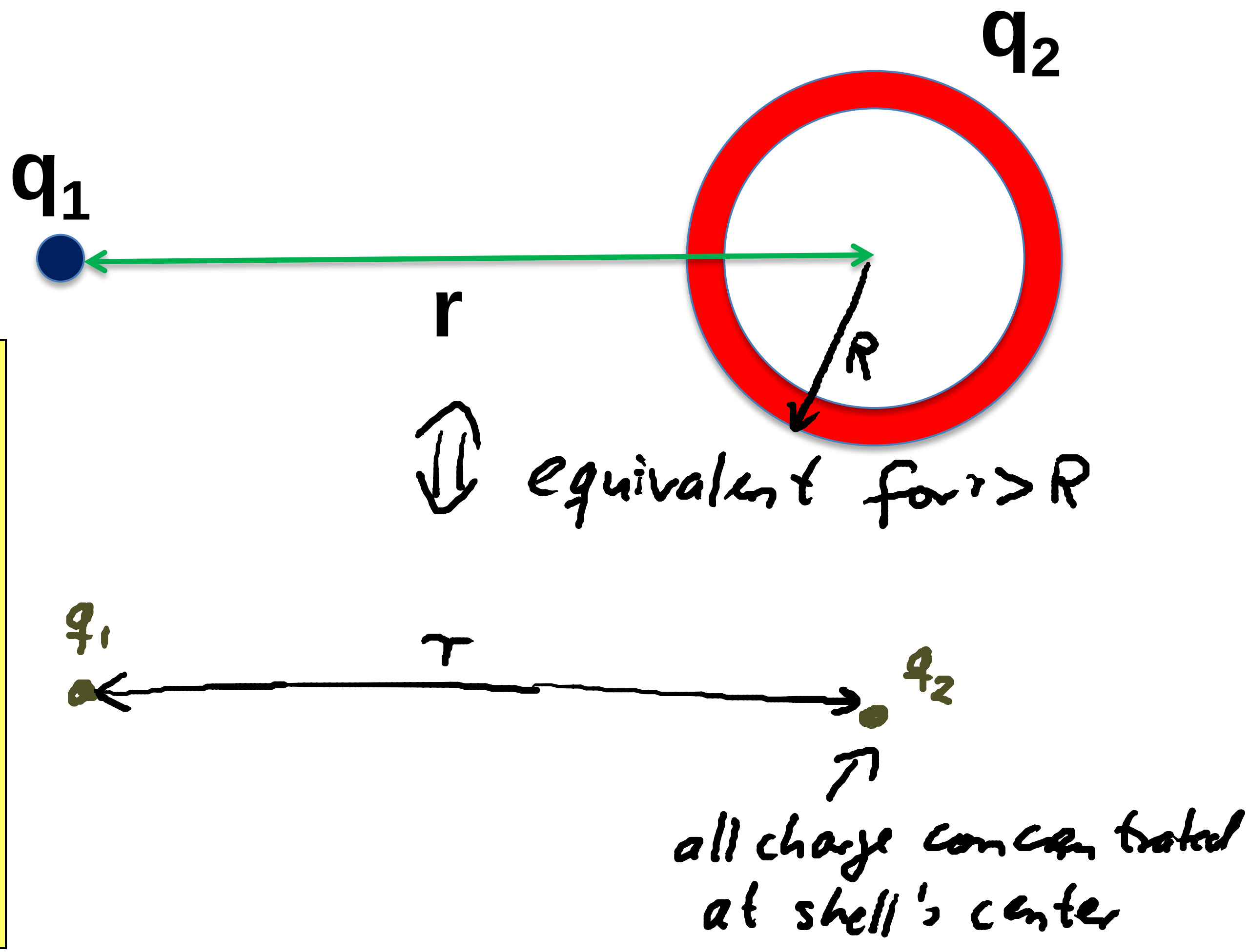
A. $F_-/4$	B. $F_-/2$
C. $3F_-/4$	D. F_-
E. None of the above.	

What is the **direction of the net electric force** acting on the particle with charge $+q$?



A. →.	B. ←.
C. ↑.	D. ↓.
E. None of the above directions.	

The electrostatic force by the shell of uniform charge q_2 an the particle of charge q_1 is…



A. $> \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

B. $< \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

C. $= \dfrac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

The electrostatic force by the shell of uniform charge q_2 an the particle of charge q_1 is…

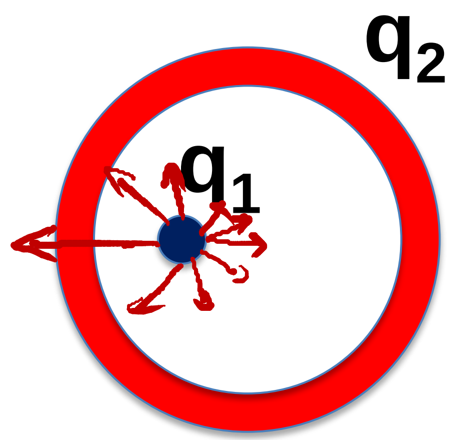
A. Pointing to the left

B. Pointing to the right

C. Pointing up

D. Pointing down

E. zero



forces cancel out ?

$\Rightarrow F_{net} = 0$ if

inside shell

Shell Theorem:

- **A shell of uniform charge attracts or repels a charged particle that is outside the shell as if all the shell's charge were concentrated at it's the shell's center.**

- **If a charged particle is located inside a shell of uniform charge, there is no net electrostatic force on the particle from the shell.**

Conductors and Insulators

- Insulator: (non conductors)
  - None of charged particles can move freely throughout the object
  - Examples: glass, some plastics, ultra pure water
- Conductors:
  - Some of the charged particles can move freely
  - Examples: Metals (outermost e^- of atoms become free to move = conduction electrons) tap water, human body
- Semiconductors:
  - between insulators and conductors
- Superconductors: – perfect conductors; charged particles can move without resistance

A PVC rod is rubbed with wool to charge the rod **negative** and then broad near a floating metal coated He-balloon, which has **no net charge**. The electrostatic force between the rod and the balloon will…

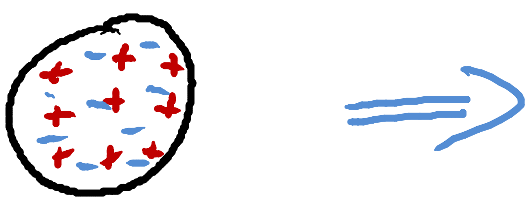
A. Push the balloon away
B. Attract the balloon
C. Nothing will happen.

A Plexiglas rod is rubbed with vinyl to charge the rod **positive** and then broad near a floating metal coated He-balloon, which has **no net charge**. The electrostatic force between the rod and the balloon will…

A. Push the balloon away
B. Attract the balloon
C. Nothing will happen.

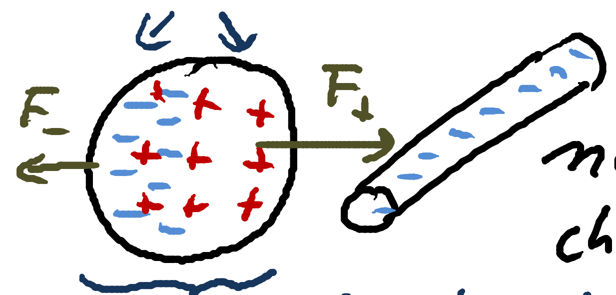
Polarization of a conductor / "induced charge"

→ separation of positive and negative charges due to presence of nearby charge ⇒ forces on electrons



neutral, conducting sphere

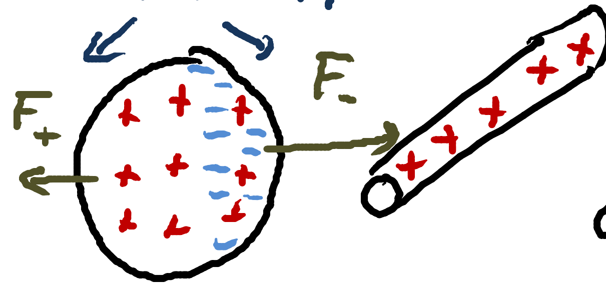
polarized!



negatively charged PVC rod

net charge of sphere still = 0!

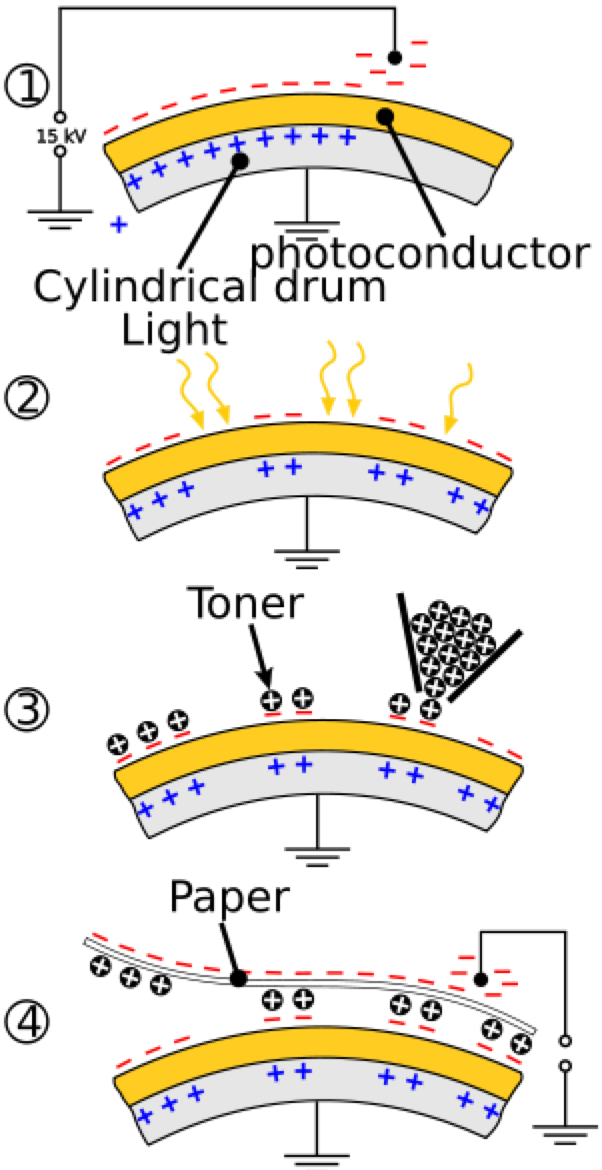
$|F| \propto 1/r^2$



positively charged glass rod

⇒ In both cases, rod attracts the sphere!

Copy Machine



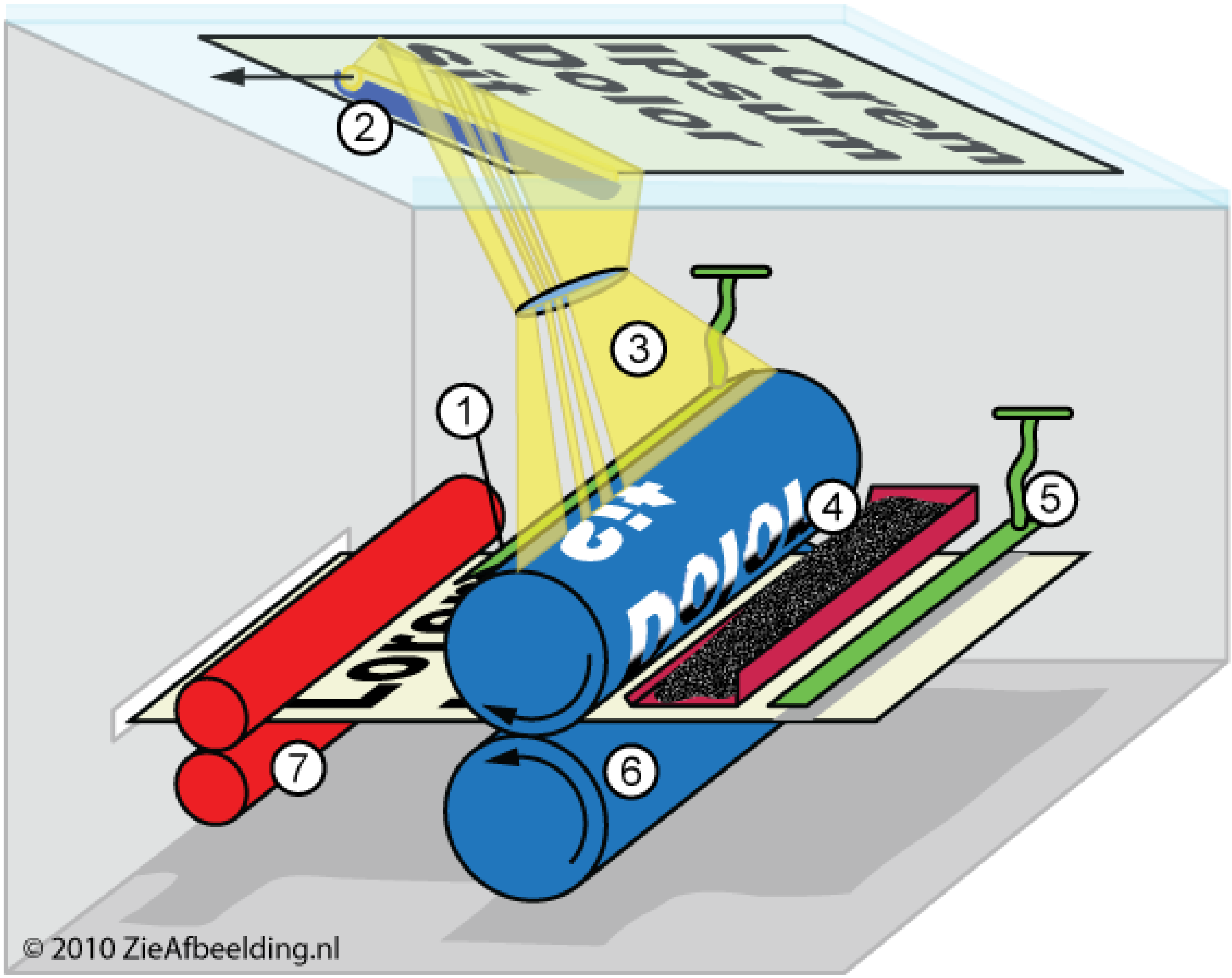
1.) Charging: cylindrical drum is electrostatically charged by a high voltage wire.

2) Exposure: A bright lamp illuminates the original document, and the white areas of the original document reflect the light onto the surface of the photoconductive drum. The areas of the drum that are exposed to light become conductive and therefore discharge to ground.

3) Developing: The toner is positively charged. When it is applied to the drum to develop the image, it is attracted and sticks to the areas that are negatively charged (black areas).

4) Transfer: The resulting toner image on the surface of the drum is transferred from the drum onto a piece of paper with a higher negative charge than the drum.

5) Fusing: The toner is melted and bonded to the paper by heat and pressure rollers.


Lorem
Ipsum
Dolor
Sit
1
2
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4
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