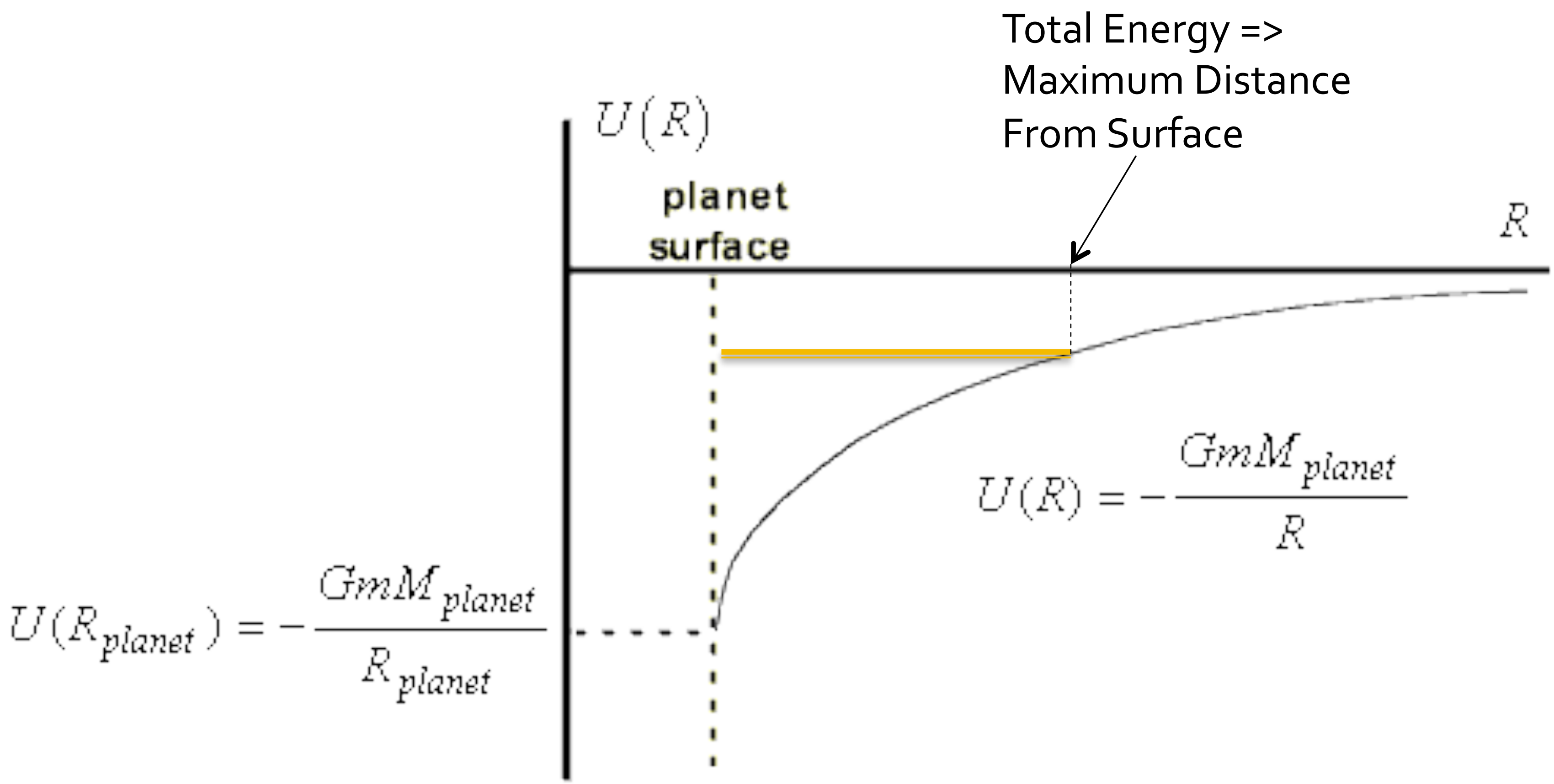
Physics II: 1702
Gravity, Electricity, & Magnetism

Professor Jasper Halekas
Van Allen 70 [Clicker Channel #18]
MWF 11:30-12:30 Lecture, Th 12:30-1:30 Discussion

Potential Well



Why Don't Objects Fall Into the Sun?

- The other important principle governing orbits is conservation of angular momentum

- $L = mv_\phi r$ = constant

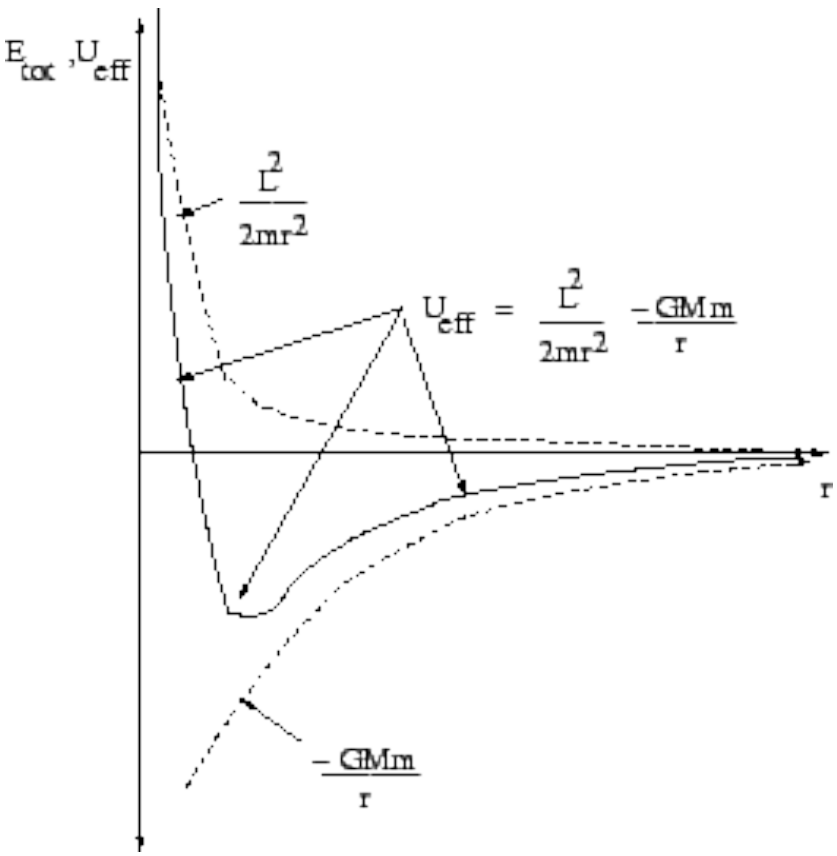
- $KE_\phi = 1/2\, mv_\phi^2 = L^2/(2mr^2)$

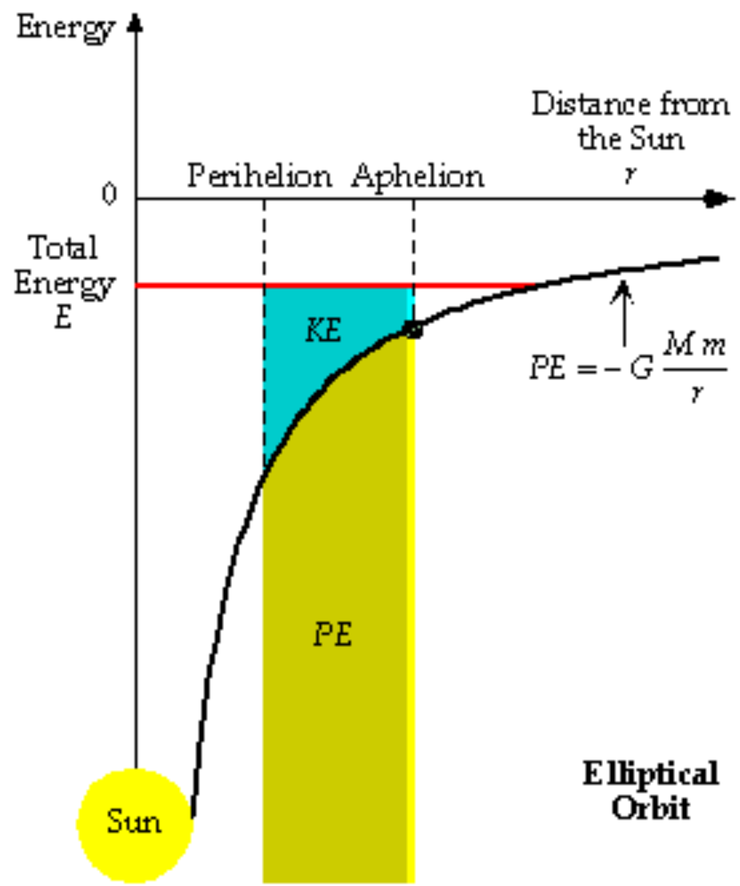
- $KE_{total} = KE_r + KE_\phi = 1/2 mv_r^2 + L^2/(2mr^2)$

- Total kinetic energy can't go below $L^2/(2mr^2)$

Total Energy in Orbit

- Energy = $1/2mv_r^2 + L^2/(2mr^2) - GMm/r$





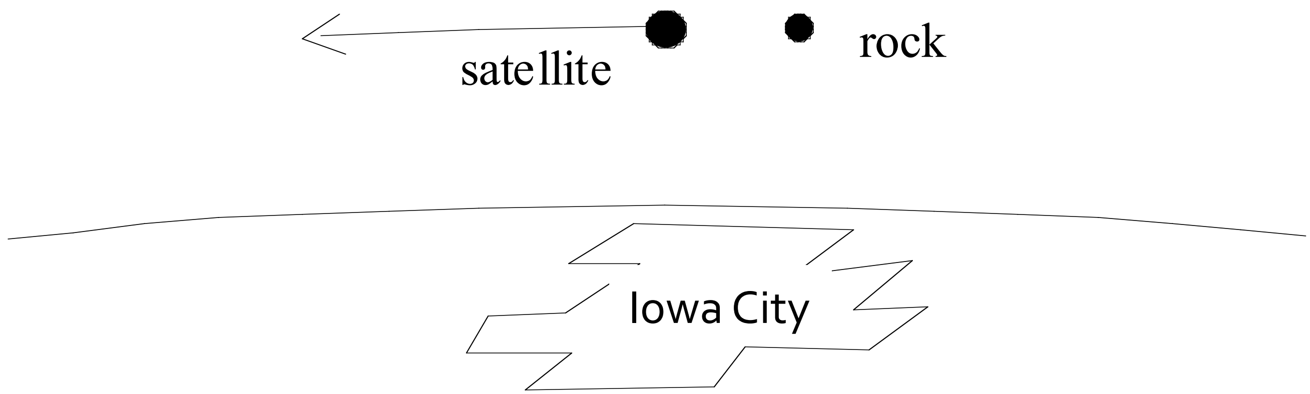
Circular Orbits

- In orbit, not all velocity is radial
- In the limit of circular orbit, radius is constant

- $F = Fg = GMm/r^2 = Fc = ma = mv^2/r$
  - $\Rightarrow v^2 = GM/r$
  - $\Rightarrow KE = GMm/(2r)$
  - $U_g = -GMm/r$
  - $E = KE + U_g = -GMm/(2r)$

Concept Check

At time t=0, a satellite in circular orbit about the Earth is directly over Iowa City, 300 miles above the city, and traveling eastward at 16,000 mph. At the same time, a rock is released from rest 300 miles above the city, very near the satellite.



True or False: Just after its release, the accelerations of the rock and the satellite are identical in magnitude <u>and</u> direction.

A) true B) False

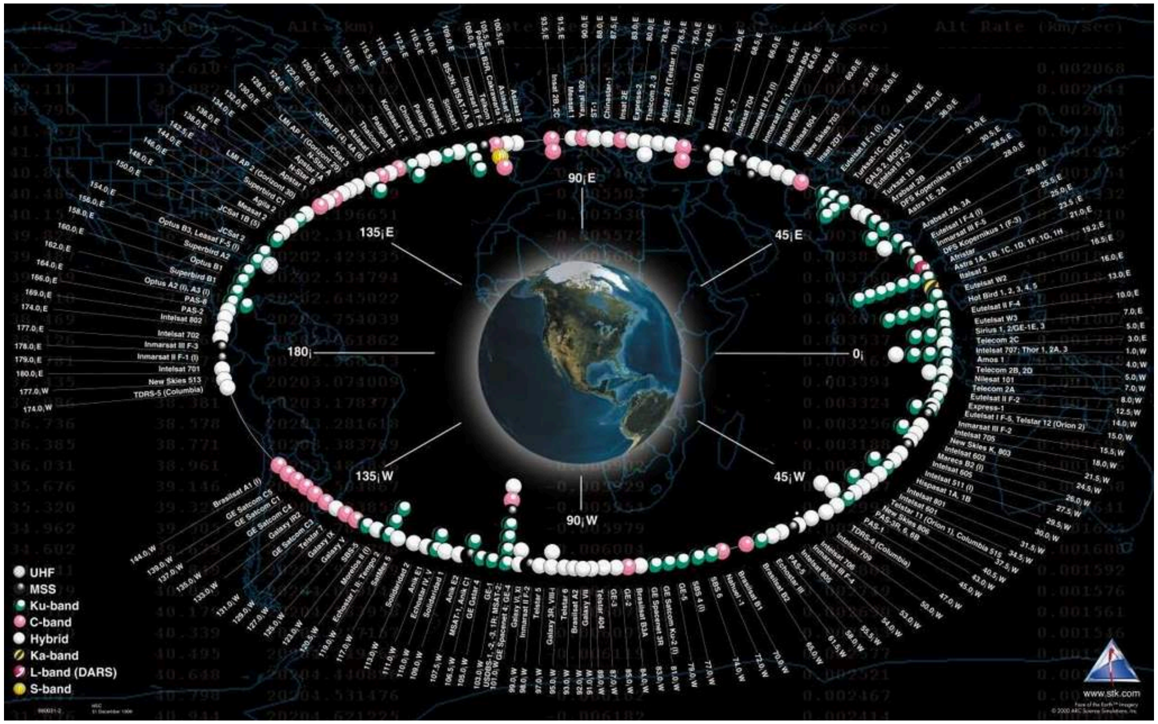
Kepler's Third Law

- For a circular orbit (can be extended to elliptical):
  - KE = GMm/(2r) = 1/2 mv^2
  - Diameter = 2πr
  - Period T = 2πr/v = 2πr/√(GM/r) = 2π√(r^3/(GM))

  - The square of the period is proportional to the cube of the orbit radius

Geosynchronous Orbit

- Orbit where T = 1 day = 24*3600 s
- => $r_{geosync} = (MG(86400/2\pi)^2)^{1/3}$
  - =42231 km
  - =6.62 R_E



Pace Poll

- The pace of the class so far is:

A. About right
B. Too fast – slow the heck down!
C. Too slow – I'm bored
D. Feels like the first 10k of a marathon
E. Like driving a car with a manual transmission for the first time

Fundamental Quantities

- You learned last semester that matter has mass
  - Mass is conserved (for non-relativistic situations)
  - Mass is only positive (barring exotic things like dark energy)

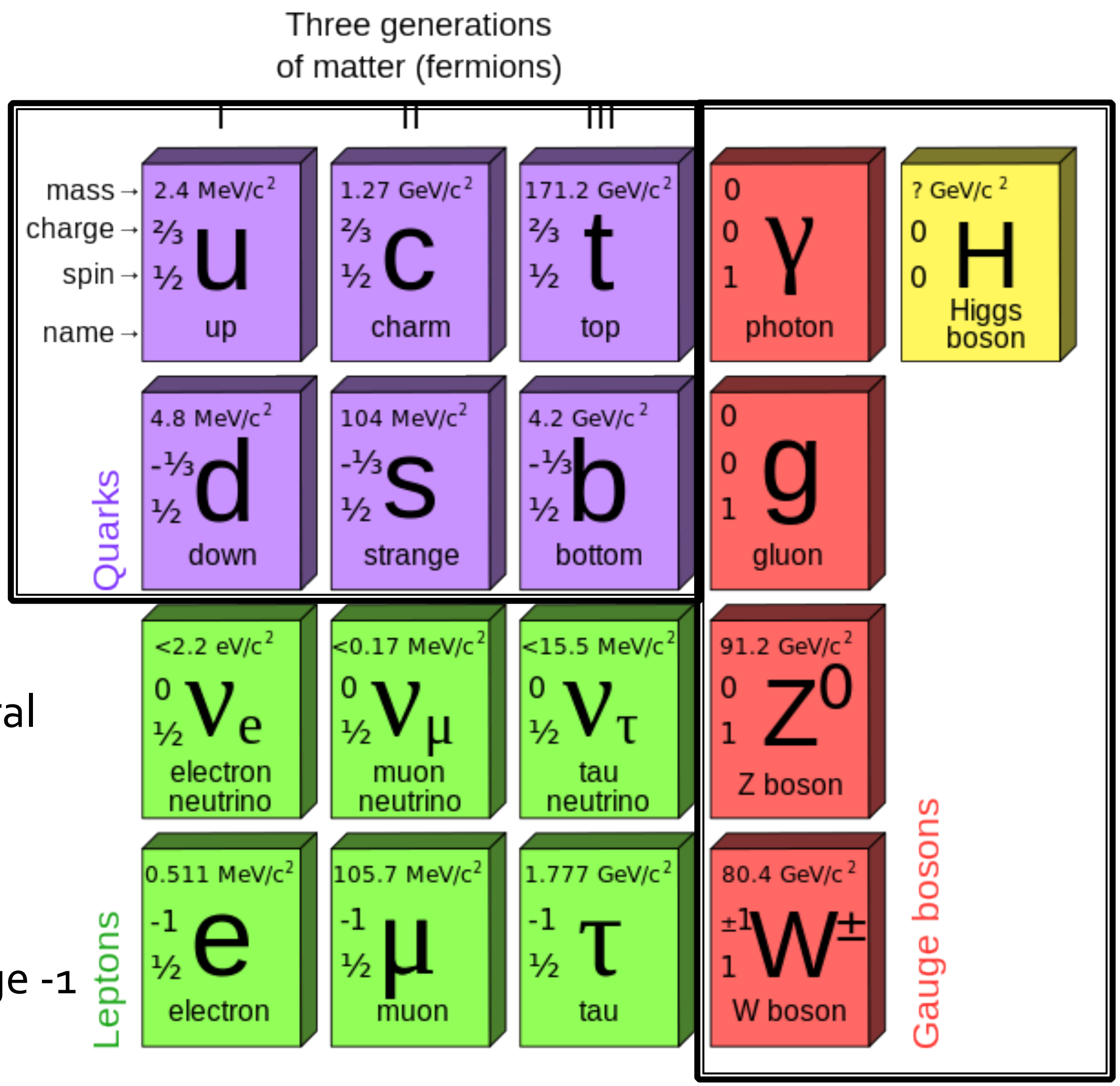
- This semester, we will learn that matter can also have charge
  - Charge is conserved
  - Charge can be positive or negative

Fundamental Building Blocks

Fractional Charge Not Directly Observable

Neutral

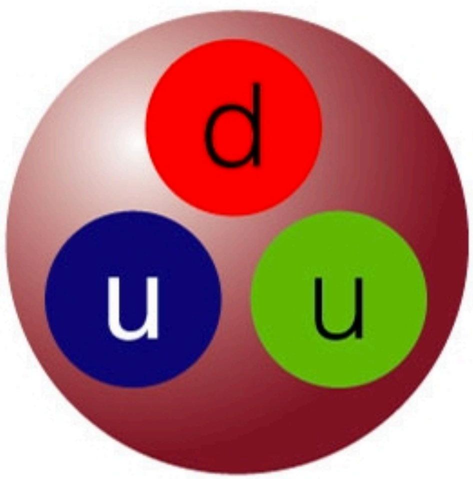
Charge -1



Don't worry about these for a few years!

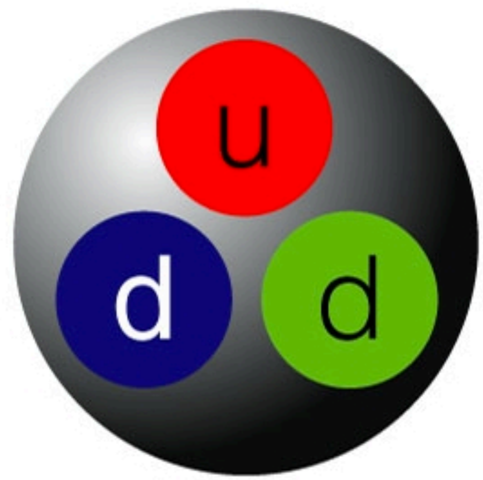
Observable Particles

A proton is composed of 2 up quarks (u) and 1 down quark (d).



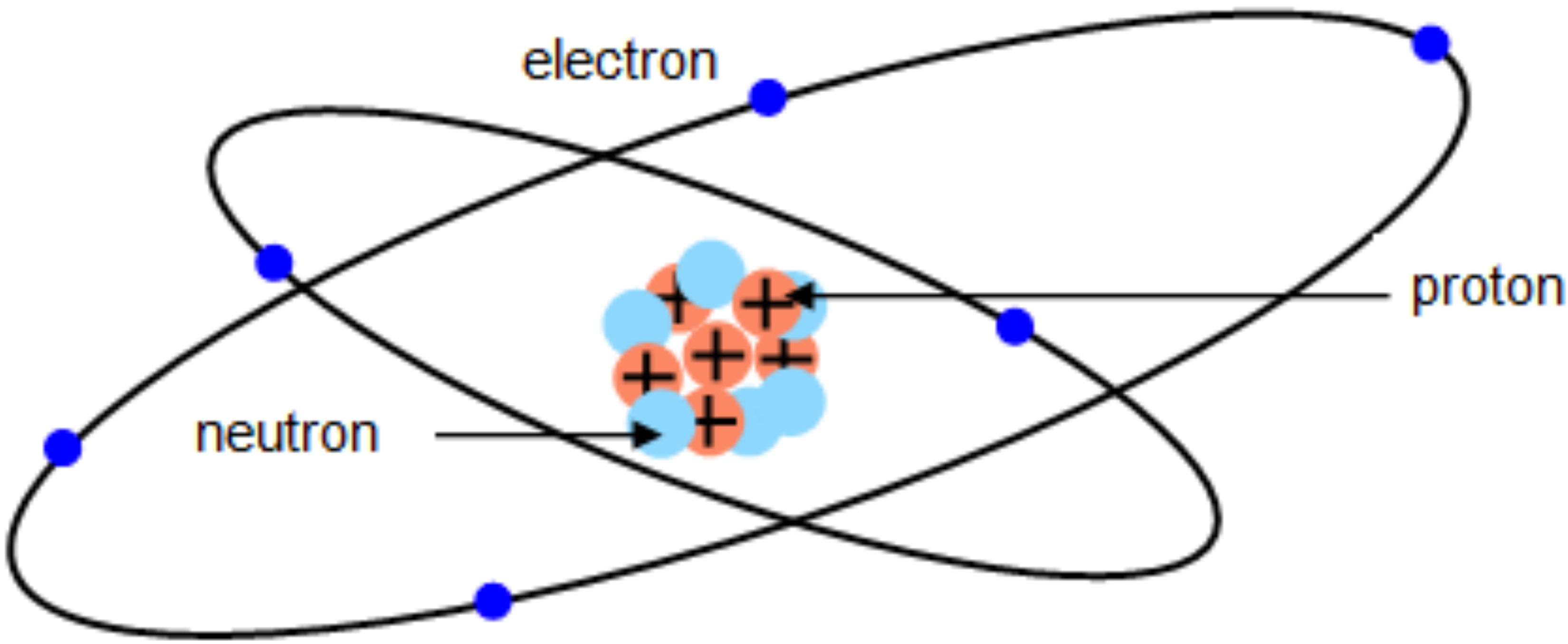
Total charge:
$+2/3 + 2/3 - 1/3 = +1$

A neutron is composed of 1 up quark (u) and 2 down quarks (d).

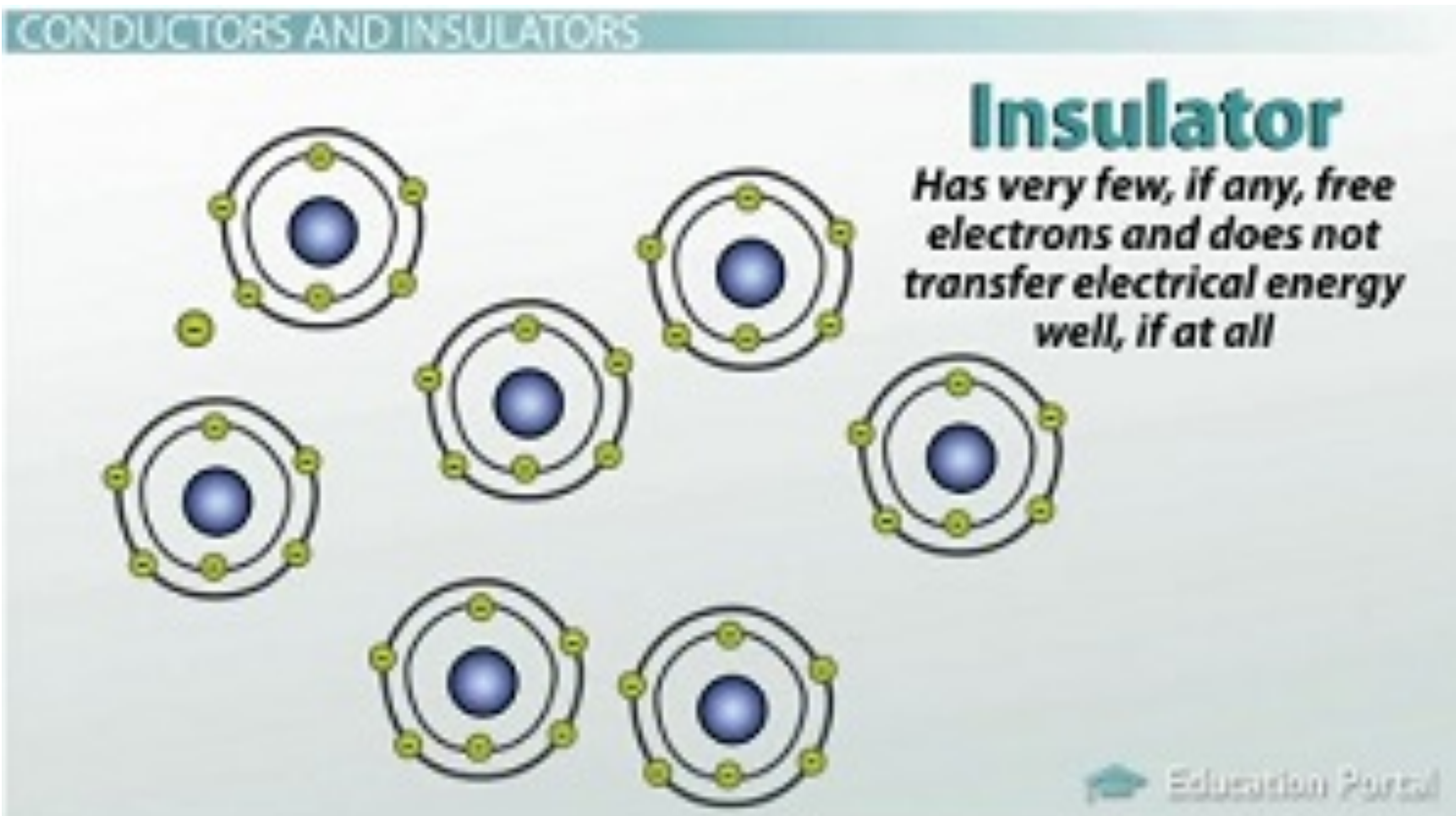


Total charge:
$+2/3 - 1/3 - 1/3 = 0$

Most of the Universe We Can See



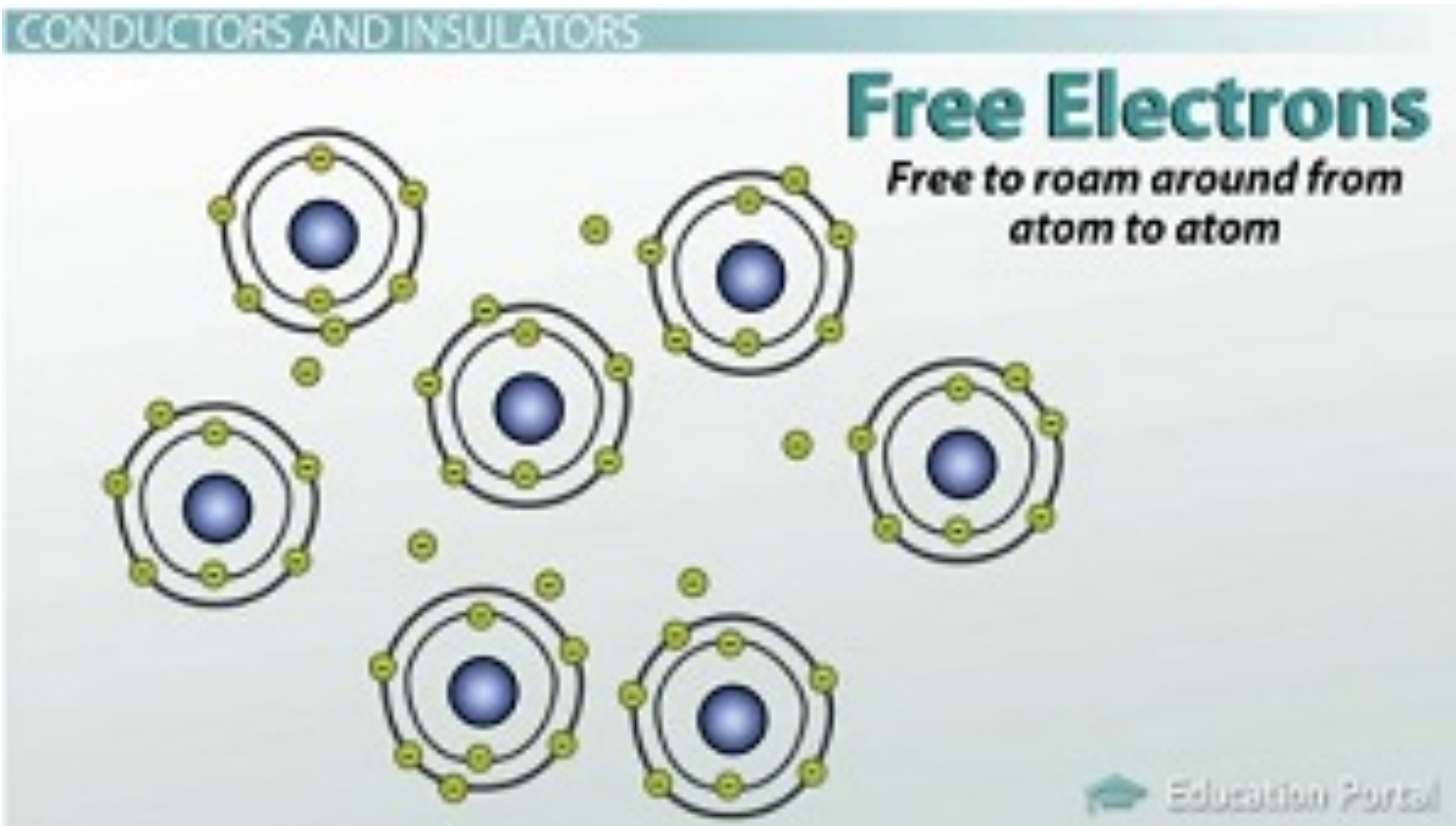
Insulators


CONDUCTORS AND INSULATORS
Insulator
Has very few, if any, free electrons and does not transfer electrical energy well, if at all
Education Portal

Charge Transfer/Distribution

- Charge (in the form of electrons) can be transferred to or from insulators
  - For instance, by rubbing (triboelectricity)
  - Or bombardment with a beam of charged particles
- Charge sticks where it is put on an insulator
  - Charges on an insulator can actually be moved slightly (polarization), but will not flow across an insulator

Conductors


CONDUCTORS AND INSULATORS
Free Electrons
Free to roam around from atom to atom
Education Portal

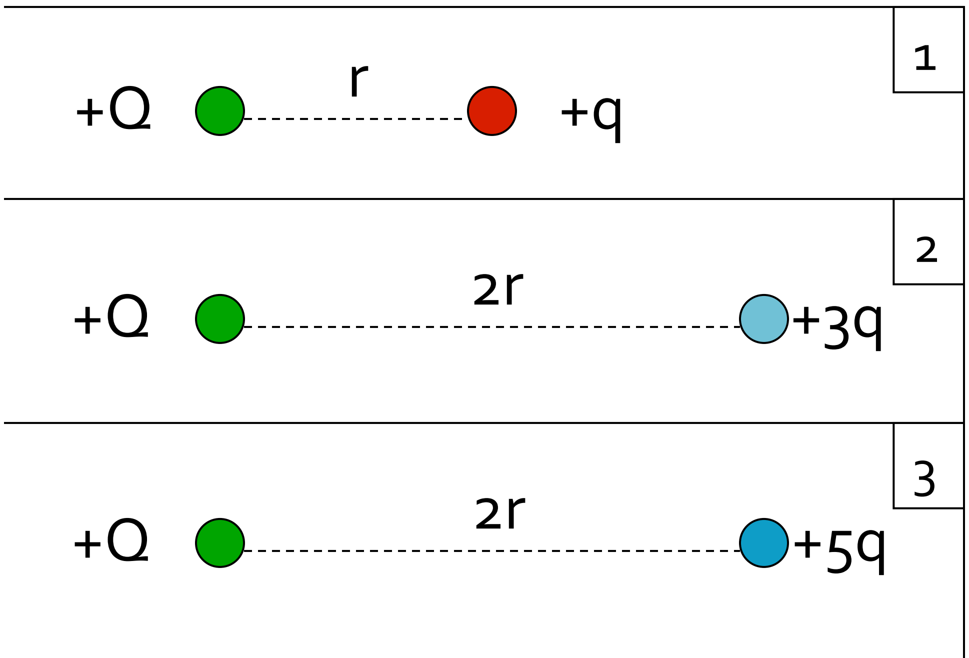
Charge Transfer/Distribution

- Charge (in the form of electrons) can be transferred to from conductors
  - Primarily by conduction (touching an object to the conductor)
- Charge is free to move on a conductor
  - As a result, it rapidly distributes itself evenly over the conductor
    - Why?
    - Because there is a force between charged particles…

Coulomb's Law

- Force between two particles $F = kq_1q_2/r^2$
  - Depends on product between two charges
  - If same sign of charge, this product is positive
    - Positive means an outward (repelling) force
      - Force on q_1 is outward from q_2
      - Force on q_2 is outward from q_1
  - If opposite sign of charge, this product is negative
    - Negative means an inward (attracting) force
      - Force on q_1 is toward q_2
      - Force on q_2 is toward q_1

Coulomb's Law Calculations



Which charge (+Q) feels the largest force?

A) +q

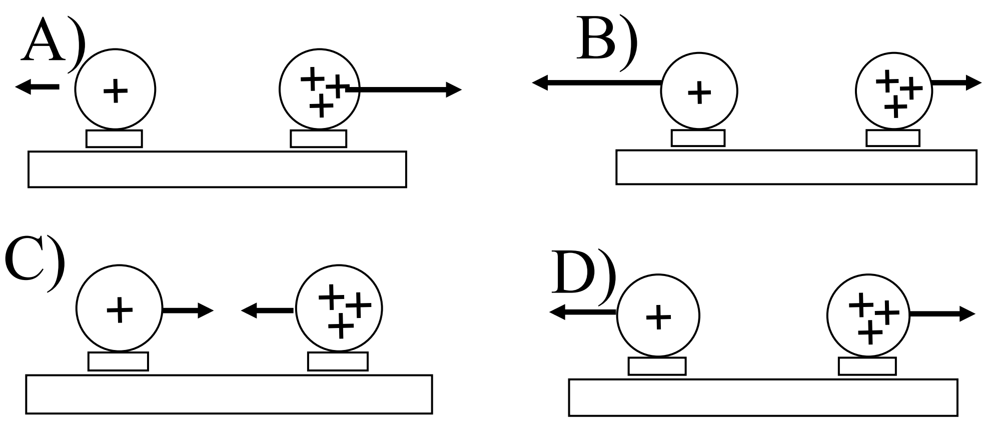
B) +3q

C) +5q

D) two of the charges tie for the largest size force.

Coulomb's Law Concept Check

Which force diagram correctly shows the relative magnitudes and directions of the electrostatic forces on the two spheres?



E) None of these can be correct