Wed. Lab Fri.	3.6-.10 Elect & Strong Force; Quiz 2 L3: Predicting Motion under Non-Constant F 3.11 –.13 Conservation of P & Multiple Particles	RE 3.b bring laptop, smartphone, pad,… bring headphones if you want RE3.c
Mon. Tues	4.1-.5 Atomic nature of matter / springs	RE 4.a EP 3, HW3: Ch 3 Pr's 42, 46, 58, 65, 72 & CP

Advising Moment:

Workload Expectations and Management

Expectations:

Management:

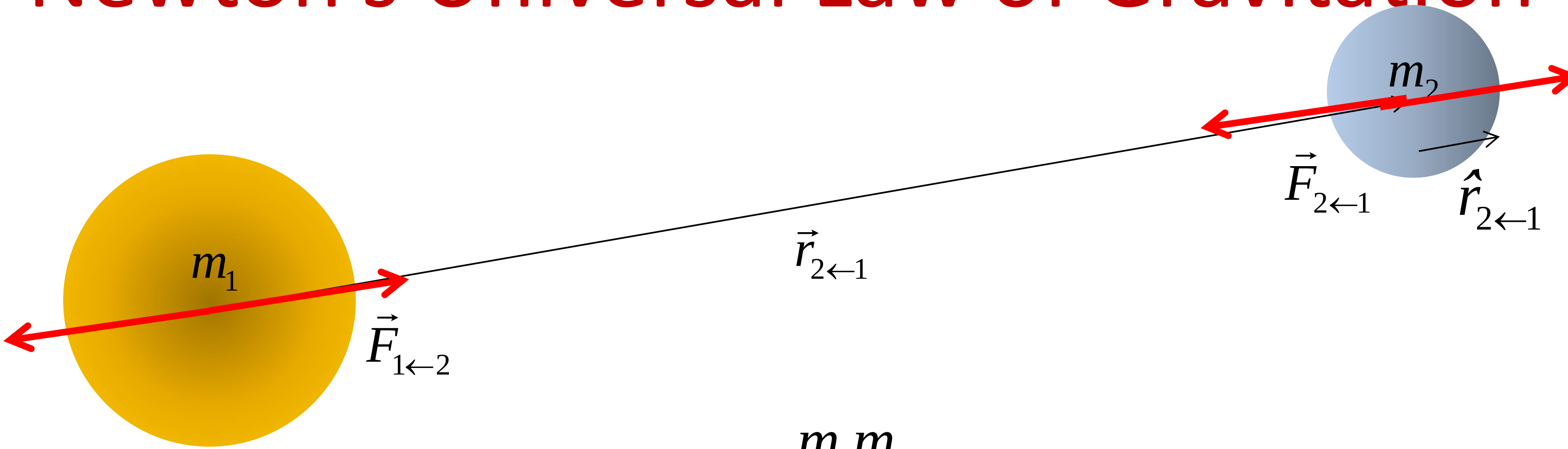
Q3.4.a

The Earth has a mass of 6e24 kg. The Sun is much more massive; its mass is 2e30 kg. Which of the following statements is correct?

a) The gravitational force on the Sun by the Earth is smaller in magnitude than the gravitational force on the Earth by the Sun.
b) The gravitational force on the Sun by the Earth is exactly the same in magnitude as the gravitational force on the Earth by the Sun.
c) Neither (a) nor (b) is correct.

You hold a tennis ball at rest above your head, then open your hand and release the ball, which begins to fall. At this moment, which statement about the magnitudes of the gravitational forces between the Earth and ball is correct?	a. The force on the ball by the Earth is larger than the force on the Earth by the ball. b. The force on the ball by the Earth is smaller than the force on the Earth by the ball. c. The force on the ball by the Earth is equal to the force on the Earth by the ball. d. There is not enough information to determine this.

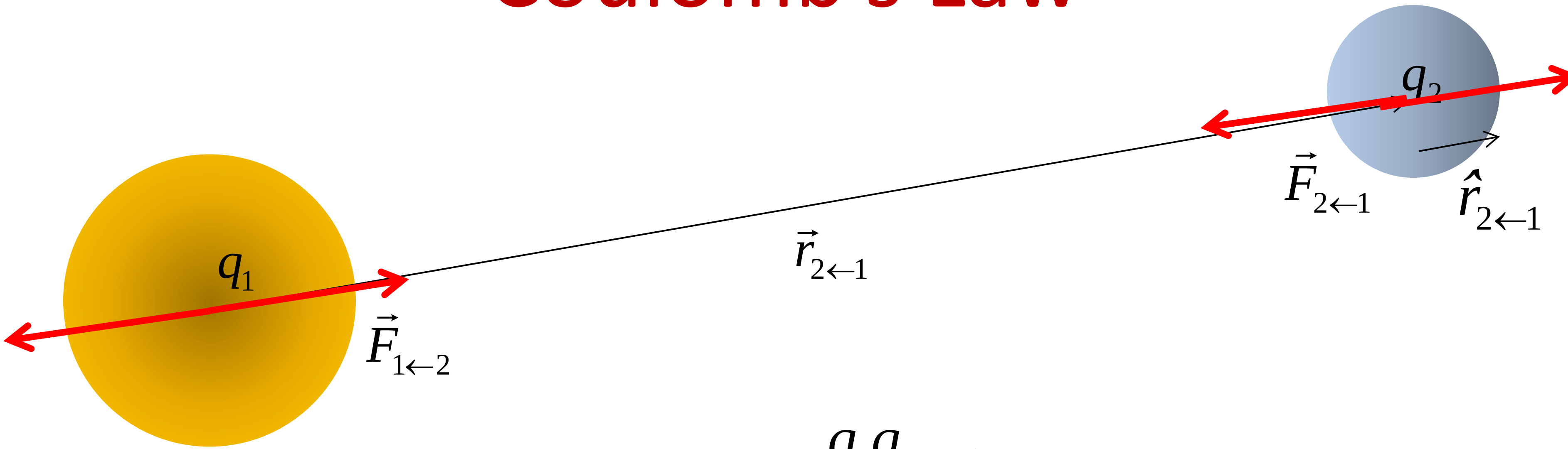
Newton's Universal Law of Gravitation



$$\vec{F}_{2\leftarrow 1} = -G\,\frac{m_1 m_2}{\left|\vec{r}_{2\leftarrow 1}\right|^2}\,\hat{r}_{2\leftarrow 1}$$

$$G = 6.67\times 10^{-11}\,\frac{N\cdot m^2}{(kg)^2} \qquad \hat{r}_{2\leftarrow 1} = \frac{\vec{r}_{2\leftarrow 1}}{\left|\vec{r}_{2\leftarrow 1}\right|}$$

Coulomb's Law



$$\vec{F}_{2\leftarrow1} = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{\left|\vec{r}_{2\leftarrow1}\right|^2}\hat{r}_{2\leftarrow1}$$

$$\frac{1}{4\pi\varepsilon_o} = 9\times10^9\,\frac{N\cdot m^2}{C^2}$$

$$\hat{r}_{2\leftarrow1} = \frac{\vec{r}_{2\leftarrow1}}{\left|\vec{r}_{2\leftarrow1}\right|}$$

An alpha particle (which contains two protons and two neutrons) has a net charge of +2e. The alpha particle is 0.1 m away from a single proton, which has charge +e. Which statement about the magnitudes of the electric forces between the particles is correct?	a. The force on the proton by the alpha particle is equal to the force on the alpha particle by the proton. b. The force on the proton by the alpha particle is larger than the force on the alpha particle by the proton . c. The force on the proton by the alpha particle is smaller than the force on the alpha particle by the proton. d. There is not enough information to determine this.

Subatomic Particles

Electron:

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

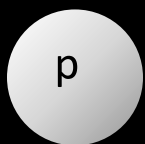
Charge: $q_e = -e = -1.6\times10^{-19}$C

Interacts electrically, gravitationally, “weakly”

Diameter: none

Status: *fundamental*

Proton:

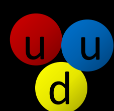


Mass: $m_p = 1.673\times10^{-27}$kg

Charge: $q_p = +e = +1.6\times10^{-19}$C

Diameter: ~ 10^{-15}m

Status: *composite*

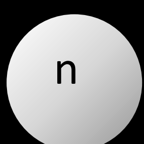


two “up” quarks +2/3 e charge

one “down” quark -1/3 e charge

interact electrically, gravitationally, “weakly”, and “strongly”

Neutron:

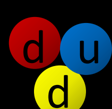


Mass: $m_p = 1.675\times10^{-27}$kg

Charge: $q_p = 0$

Diameter: ~10^{-15}m

Status: *composite*



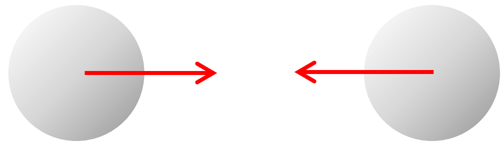
one “up” quark +2/3 e charge

two “down” quarks -1/3 e charge

interact electrically, gravitationally, “weakly”, and “strongly”

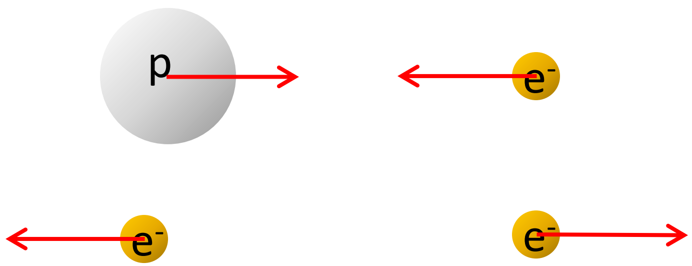
Fundamental Properties and Interactions

Mass & Gravitation



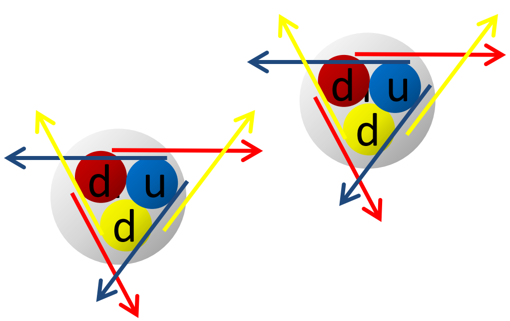
$$\vec{F}_{2\leftarrow 1} = -G\frac{m_1 m_2}{\left|\vec{r}_{2\leftarrow 1}\right|^2}\hat{r}_{2\leftarrow 1}$$

Charge & Electrical

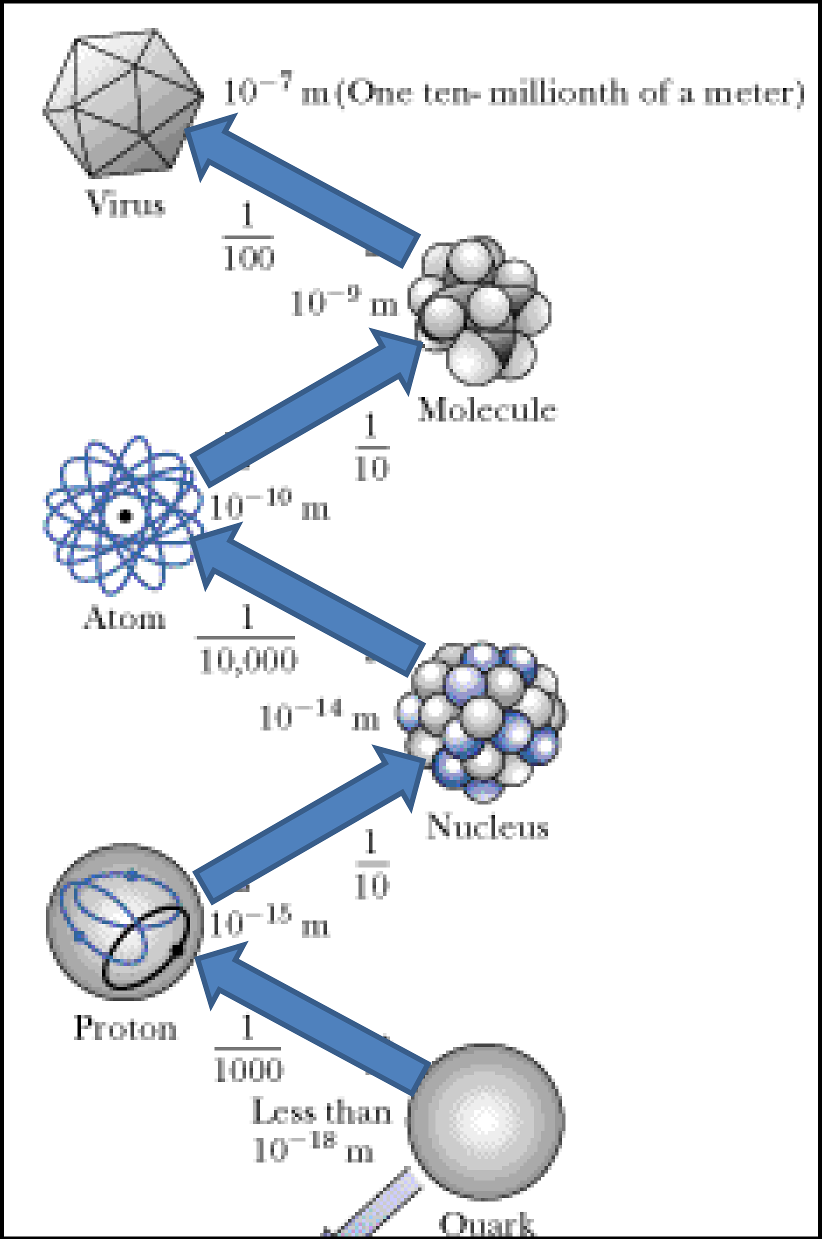


$$\vec{F}_{2\leftarrow 1} = \tfrac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{\left|\vec{r}_{2\leftarrow 1}\right|^2}\hat{r}_{2\leftarrow 1}$$

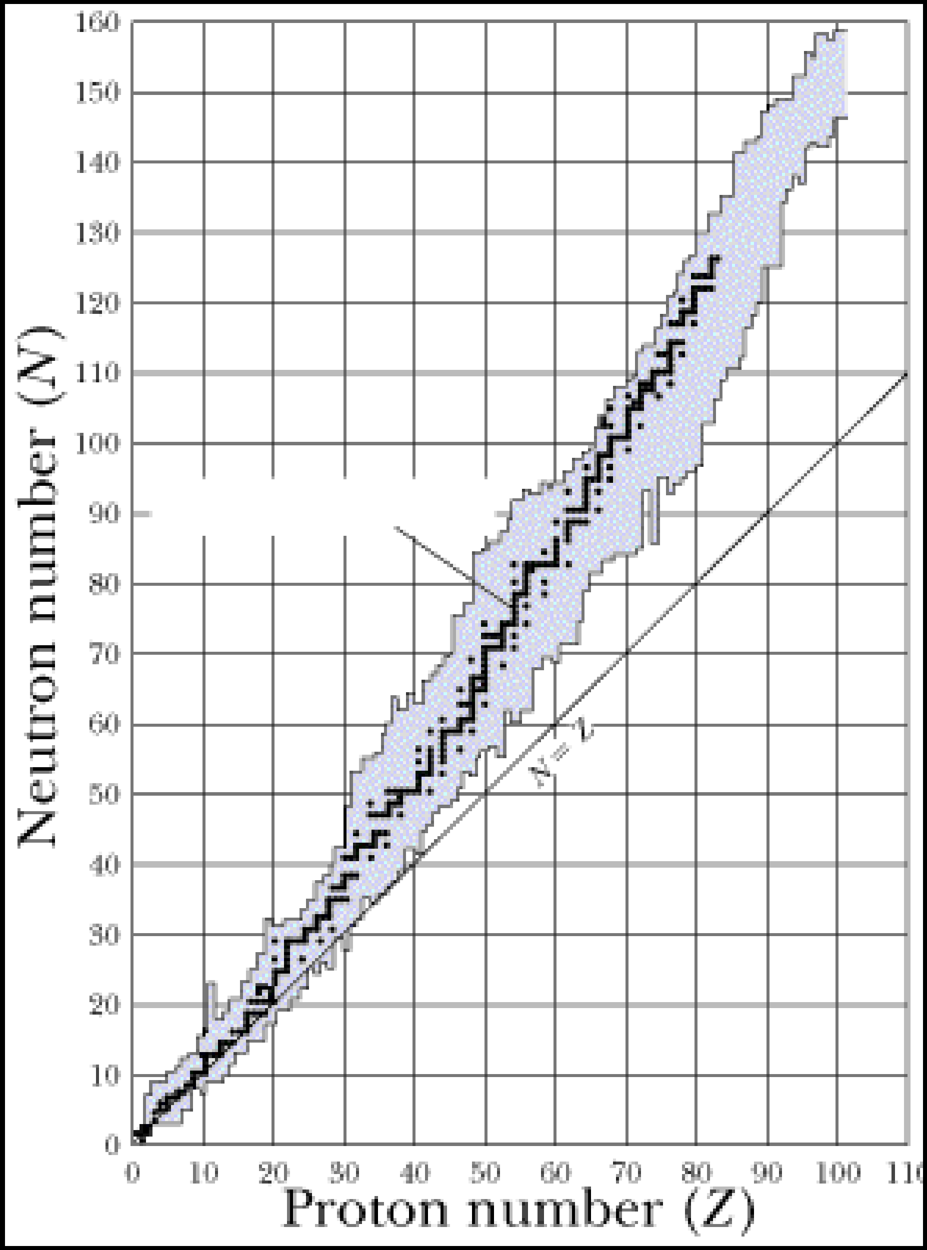
"Color" & Strong



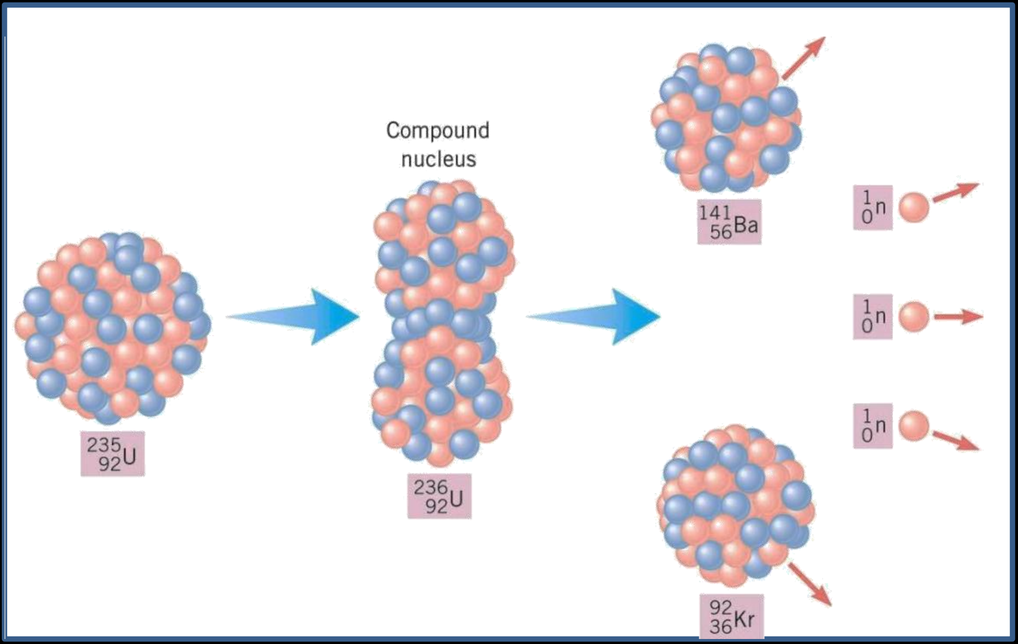
Protons + Neutrons = Nuclei



Nuclear Stability: Coulomb vs. Strong



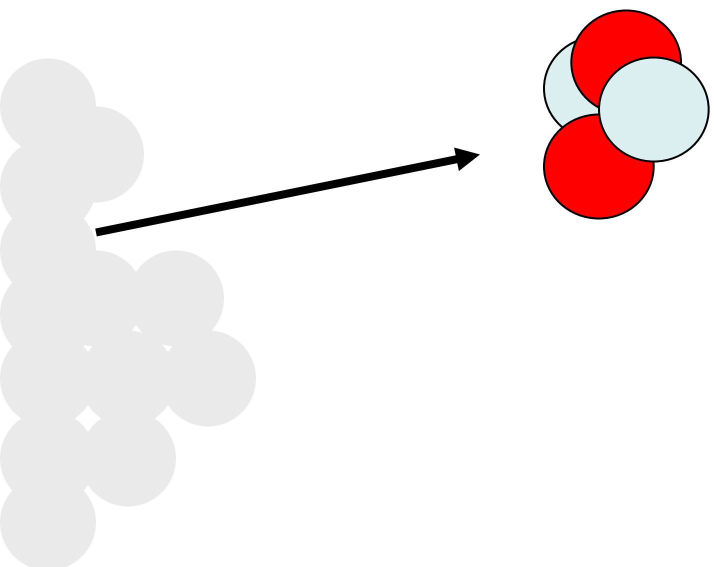
Nuclear *in*stability



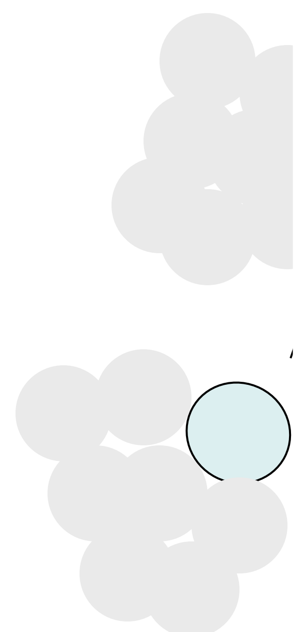
Nuclear *in*stability: Decay Modes (electric and weak interactions)

α decay

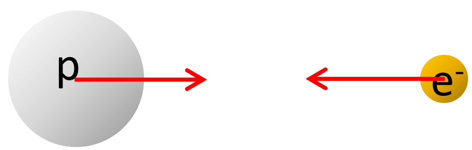
α Particle = 2p + 2n



β^- decay



Atoms: Electrical 'solar systems'



$$\vec{F}_{e\leftarrow p} = \frac{1}{4\pi\varepsilon_o}\frac{q_e q_p}{\left|\vec{r}_{e\leftarrow p}\right|^2}\hat{r}_{e\leftarrow p}$$

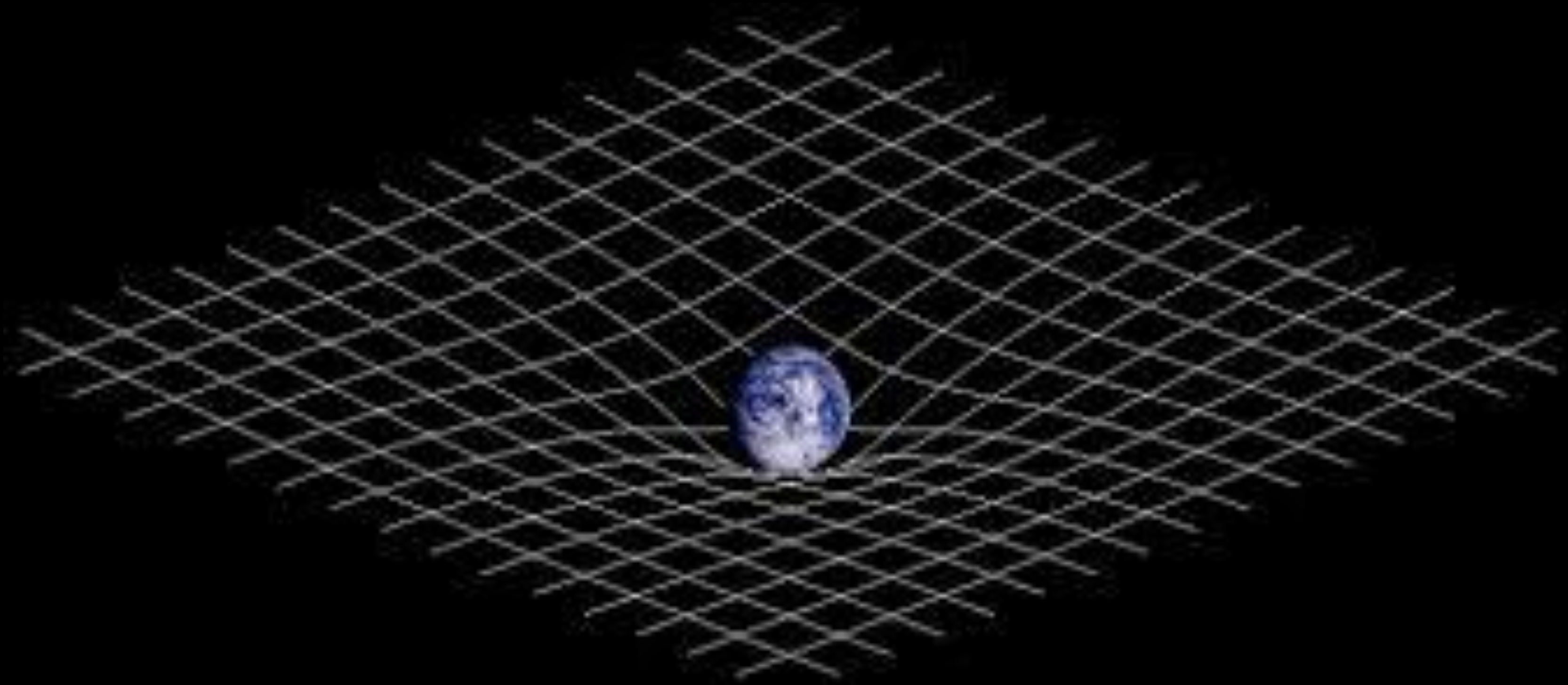
$$\vec{F}_{e\leftarrow p} = \frac{1}{4\pi\varepsilon_o}\frac{(-e)(e)}{\left|\vec{r}_{e\leftarrow p}\right|^2}\hat{r}_{e\leftarrow p}$$

Same form as

$$\vec{F}_{Earth\leftarrow Sun} = -G\frac{M_E M_S}{\left|\vec{r}_{E\leftarrow S}\right|^2}\hat{r}_{E\leftarrow S}$$

Forces and *alternative* Representations of "Interactions"

Mass's dual role …General Relativity



(note: more realistically – 3D grid puckered)

Predicting the future of Complex Systems

- Too Many Objects
  - Example: three-body gravitational system

$$\vec{F}_{2\leftarrow total} = \vec{F}_{2\leftarrow 1} + \vec{F}_{2\leftarrow 3} = -G\frac{M_1 M_2}{\left|\vec{r}_{2\leftarrow 1}\right|^2}\hat{r}_{2\leftarrow 1} - G\frac{M_3 M_2}{\left|\vec{r}_{2\leftarrow 3}\right|^2}\hat{r}_{2\leftarrow 3}$$

$$\vec{F}_{1\leftarrow total} = \vec{F}_{1\leftarrow 2} + \vec{F}_{1\leftarrow 3} = -G\frac{M_1 M_2}{\left|\vec{r}_{1\leftarrow 2}\right|^2}\hat{r}_{1\leftarrow 2} - G\frac{M_3 M_1}{\left|\vec{r}_{1\leftarrow 3}\right|^2}\hat{r}_{1\leftarrow 3}$$

$$\vec{F}_{3\leftarrow total} = \vec{F}_{3\leftarrow 2} + \vec{F}_{3\leftarrow 1} = -G\frac{M_3 M_2}{\left|\vec{r}_{3\leftarrow 2}\right|^2}\hat{r}_{3\leftarrow 2} - G\frac{M_3 M_1}{\left|\vec{r}_{3\leftarrow 1}\right|^2}\hat{r}_{3\leftarrow 1}$$

- Too Sensitive Dependence: “chaos”
  - Example: double pendulum

- Practical Limits to Determinism

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