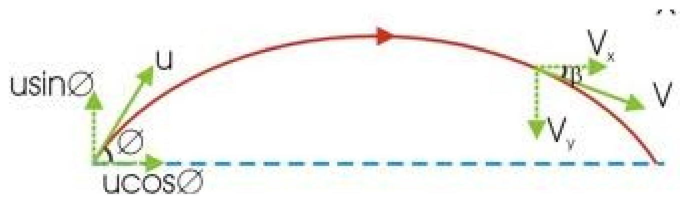
SPACE, TIME, & MATTER

Physics – "Statement of Purpose"

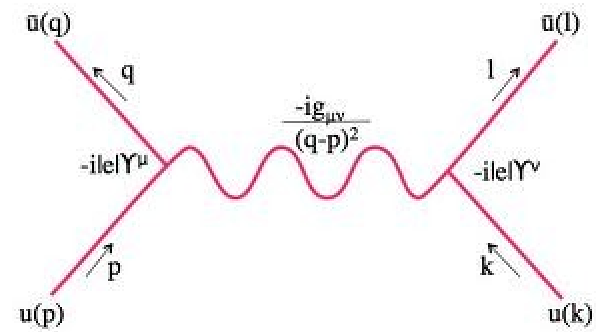
- To investigate the nature of 3 fundamental concepts:

Space

Time / Motion



Matter

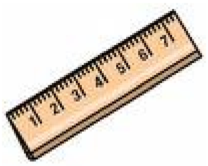


- "Newtontian" or "Classical" Physics:
  - treats Space, Time, and Matter as separate entities

- Einstein's "Relativistic" Physics (early 20th century)
  - shows Space, Time, and Matter (energy) are all "intertwined"

History of Physics – (very) Brief Version

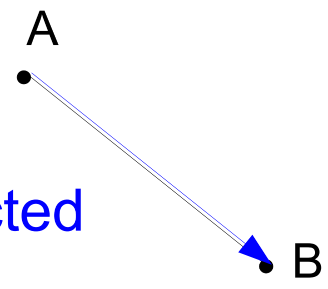
- Define ways to measure space, time and matter (units)
  - “Standard” units have improved in precision over the years
  - The “SI” system of units:
  - Space: meter (m)
  - Time: second (s or sec)
  - Matter: kilogram (kg)



- Measure relationship between space, time, and matter
  - In as many situations as possible
  - With as much precision as possible
  - Create/revise theories to predict/explain the results

What is Space?

- A collection of interconnected "points"
  - These are abstract – no particular coordinates (yet)
  - Measurement → learn about how points are connected
  - Newtonian view:
  - Existence and structure of space is independent of matter
  - Points are infinitesimally small, and infinitely numerous
  - Points are distinguishable, and can be "named": ("A", "B", ...)

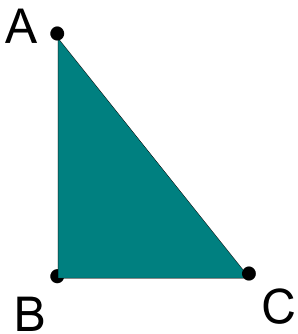


- What aspects of space can be defined and measured?
  - For 2 particular points A and B, can measure:
  - "distance" between A and B (defining units of length)
  - "direction" from A to B (can be expressed in a variety of ways)
  - Distance and direction together: "displacement vector"

“Building” Geometry

- Using distance, direction, and “if-then” logic:
  - Construct “theorems” → test by measurement
  - Use theorems as basis for higher-level theorems

- Example: Pythagorean Theorem
  - If: direction(A, B) perpendicular to direction(B, C)
  - Then: $\text{dist}(A, B)^2 + \text{dist}(B, C)^2 = \text{dist}(A, C)^2$
  - Prove it! (Given $A_{square} = L^2$ & $A_{triangle} = 0.5\ b\ h$)

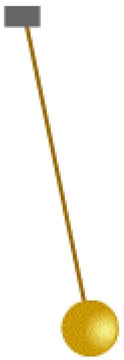


- Example: “Curved” Space
  - City A: 1000 km north of city B City C: 1000 km east of city B
  - Distance(A, C) is not 1414 km → need different “geometry”

<u>Measuring Time / Motion</u>

- <u>Newtonian view</u>: Ordered series of "instants"
  - Instants are <u>distinguishable</u>, and can be "named": ("A", "B", ...)
  - Interval between instants A and B → same throughout space
  - Instants are infinitesimally short, and infinitely numerous

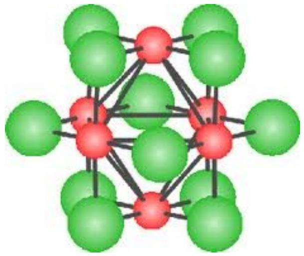
- Why are time / motion fundamentally linked?
  - How would Julius Caesar measure one second?
  - <u>All</u> of our concepts of time are linked to motions

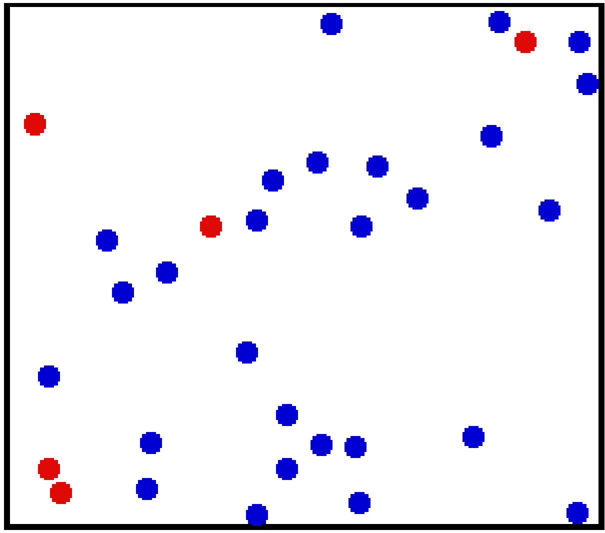


- <u>Example</u>: Measure pendulum position at <u>one</u> instant
  - Gives no information about its velocity
  - <u>To measure motion</u>: must measure over some interval Δt
  - If Δt is tiny → imprecise measurement – "uncertainty principle"

Measuring Matter

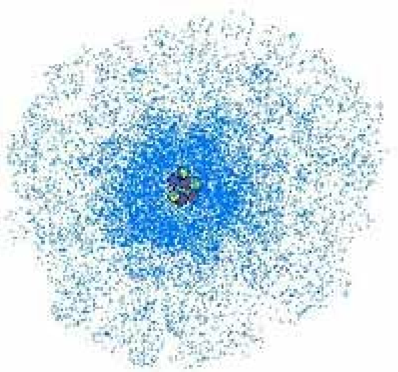
- "Mathematics" of matter
  - Not intuitively obvious – what are the fundamental "elements"?





- Newtonian approach:
  - Elements: "particles" (abstract)
  - Each particle has:
  - 1) # of kilograms of "mass"
  - 2) location (a single point) at every instant of time
  - Particles influence the location of other particles using forces
- Tough to measure mass directly – particles are tiny
  - Can measure mass indirectly by measuring force

Matter Distributions



- Another model for matter:
  - Mass of a “particle” can be distributed over many points
  - Pro: Mass need not be infinitely concentrated at one point
  - Con: Mathematical description of motion is more complicated

- “Distributions” vs. “Point Particles”
  - Can be difficult to tell the difference if:
  - 1) Mass of a distribution spans a very small distance
  - 2) Many point particles are tightly packed

- Rock thrown through air
  - Treat as a point particle for describing its flight
  - Treat as a distribution for describing spin, air resistance, etc.