“Physics 1” in 1300: Natural Philosophy and the Medieval University

Merton College, Oxford
Last time ...

- **Kepler’s physical astronomy**
  - First fundamental critique of Aristotle, in the shift from two physics to one physics
    - Crystalline spheres replaced by magnetism to keep planets in their orbits
    - Invisible force acting at a distance!
    - Circles in heavens replaced by ellipses
  - Three empirical laws of planetary motion
    - Elliptical orbits with Sun at one focus
    - Equal areas swept out in equal times
    - Harmonic law: $P^2 = a^3$
    - Quantitative prediction improved (but not new!)

- **The concepts**
  - Retrograde motion, hippopede, epicycle, deferent, equant, saving the phenomena, stellar parallax, crystalline spheres
Value of medieval physics?

- **Obstacle to modern science?**
  - Suggested by Prof. Gleiser last time
  - Claimed by creators of the “new” sciences of the Scientific Revolution (“ancients” vs. “moderns”)

- **Roots of modern science?**
  - Pierre Duhem thesis, 1913

- **Recent views**
  - Coherent philosophy to be understood on its own terms, but provided texts and questions for what would become “modern science”
Task of lecture

- Emergence of European medieval universities in twelfth century
- Legacy of Aristotelian philosophy in the universities
- Relation of medieval natural philosophy to new sciences of seventeenth century
Why new universities in 12c?

- Predecessors
  - Seven liberal arts codified by 200 in Latin encyclopedias
    - Trivium = grammar, rhetoric, logic
    - Quadrivium = arithmetic, geometry, music, astronomy (where is physics?)
  - Cathedral Schools mandated by Charlemagne, c. 800

- European conditions around 1200
  - Political stability, economic prosperity
  - Influx of Greek knowledge via translations into Latin from Arabic and Greek (Spain the center)
  - Cistercian Order founded 1098 in Burgundy
    - New secular values, based on manual labor, rejection of feudal revenues, economic self-support of each abbey
    - Rapid growth--338 abbeys by 1150, from Sweden to Greece
    - Supported urban life and commerce
    - Introduced technological innovations in farming
The university movement

- **Guild model** = self-governing group who set curricula & teachers
  - Monopoly on Latin learning, excluded women
  - Paris/Oxford model
    - Association of masters, under Bishop of Paris (theology supreme)
  - Bologna model
    - Association of law students who elected faculty (law and medicine supreme)

- More than 70 universities founded by 1500
  - Ca. 750,000 students from 1350-1500 (<< 1% population), i.e., demographically insignificant
  - Average university had about 400 students, largest in Paris might have 1000 students enrolled
Life at the medieval university

- Four faculties: arts, medicine, law, theology
- Bachelors (4 yrs), masters (6 yrs), doctors (docere) in knightly ceremonies; most students left after 2 years without earning a degree
- Standardized curriculum
  - 7 liberal arts + Aristotle for arts faculty
    - Scientia=organized human knowledge
  - Specialized texts for “higher” faculties
- Classroom pedagogy (no research!)
  - Lectures, questions, disputations
  - Ideology of “liberal arts” as not practical
  - Goal was to train bureaucrats for the emerging states, but practical matters were learned in apprenticeships outside university
Aristotle and Scholasticism

- Questions as the basis of scholasticism
  - “Let us inquire whether ...”
  - Stresses logic-rhetoric, not experimentation which “violates” nature’s “inner principles”
  - Understanding “inner principles” is goal of natural phil.

- Aristotle and Christian theology
  - Thomas Aquinas (d. 1274) and synthesis
  - “Condemnation of 1277” in Paris; 219 propositions condemned by Bishop of Paris
    - Eternity of the world?
    - Doctrine of double truth?
    - Limits on God’s absolute power?
      - “God could not create an accident (hot) without a subject (rock).”
    - Condemnations generally annulled by 1325
Dynamics (causes) of motion

- Aristotle: **external** mover required for every moving body, in direct contact
  - Nature abhors a vacuum
- Philoponus (6c Alexandria): impressed force as mover, **internal** to the moving body
- Jean Buridan (14c Paris): “impetus theory”
  - Empirical examples to refute Aristotle on motion
  - Impressed “force” but acts like Aristotelian cause
- William Ockham (14c Oxford): fewer are better
  - Coexistence of object over different parts of space is not an “effect,” requires no cause for explanation
  - Razor shaves away unneeded words
Problems with Aristotle’s “force law”
- Velocity proportional to Force/Resistance
  - If $R = 0$, $V$ becomes infinite (but logically impossible)
  - If $F$ decreases, $V$ never reaches 0 (but empirically wrong)

Th. Bradwardine’s (14c Oxford) alternate laws
- Explored expressions such as:
  - $V$ proportional to $F - R$ (rejected)
  - $V$ proportional to $(F - R)/R$ (rejected)
  - $V$ increases arithmetically as $(F/R)$ increases geometrically, i.e., to triple $V$, must cube $(F/R)$
  - Keeps $F > R$ but avoids discontinuities
  - Sought mathematical and logical coherence, not experimental confirmation (like Galilieo!)
Kinematics (i.e., mathematical description) of motion

“Latitude of forms”, Merton College
- “Form” = any quality that varies continuously on a single axis (e.g., hot/cold), Aristotelian idea
- Graphical representation of temperature of an iron bar of given length, with right end in fire
Latitudes of velocity vs. time

- Uniform velocity
- Uniformly non-uniform velocity (= uniform acceleration)
- Nonuniformly nonuniform velocity
- Breakthrough (origins not known)
  - Area of figure = Distance traveled!
- Merton College Rule (= mean speed rule)
  - Distance covered in time (t) at uniform acceleration is same as that traveled at mean speed
Proof of Merton College Rule

- Logic not experiment!
- Not applied to free fall!

D = 1/2 V_f T [area of triangle] = V_m T [area of rectangle]

Recall that a = (V_f - V_i) / T, by def; this means D = 1/2 aT^2!
The Mertonians did NOT notice this; but Galileo did!
Medieval natural philosophy and the Scientific Revolution?

- Preconditions for a new science?
  - Translations of Greek texts
  - Universities as sites for debate on natural philosophy
  - Détente with Christian theology

- Substantive contributions?
  - Studies of motion (context for Galileo?)
  - Discussions of matter and vacua (mechanical philosophy?)
  - Some experimental studies (but rare!)
    - Theodoric of Freiburg (1300) on rainbow
    - Experimentally traced path of light through spherical flasks filled with water