Chapter 9

Newton and the Modern Science

9.1 Homework

Readings – DW 18-21, Newton, selections (Bb)

Study questions – Give a short answer to the following questions:

1. Explain how the revival of the atomist theory helps making sense of the principle of inertia.
2. Is a mechanistic view of the world incompatible with the idea that God is the creator? Explain
3. Explain why the notion of gravity does not fit quite well in a mechanistic view of the world? What was Newton's attitude toward gravity?
4. Explain how Newton's view of the universe spread outside of its original domain.
5. Gather the various passages in which Newton explains what methodology he favors for natural philosophy (= physics). Do you think that these passages are consistent with one another? If yes, what is the methodology that Newton advocates? If no, what are the conflicts?
6. Newton distinguishes between absolute and relative space. Can we observe absolute space?
7. Newton attempts to show that we can observe absolute motion (p. 143-144). Explain the experiment he describes. Do you think the experiment is a convincing proof that absolute motion exists? Why?
8. Newton's explanation of the motion of bodies in terms of gravity was criticized by many. What do you think were these criticisms? How does Newton argue that gravity that appealing to gravity is an important step in scientific knowledge even if we don't know the cause of gravity itself?
9. How do you understand the idea that God is always everywhere in Newton's text?

9.2 Introduction

Our goals for the chapter:

1. See the basis of Newton's physics and Newton's scientific method
2. See how Newton's physics became the basis of a new worldview

9.3 Newton's *Principia*: overview

Newton's physics – three laws of motion + universal gravitation

First Law – Inertia

Galileo: the boat thougth experiment – circular inertia

Descartes formulates the principle of inertia for the first time

Second Law – Change in motion proportional to force applied

$$F = ma$$

Third Law – Action / Reaction

Universal Gravitation – characteristics:

- Mutually attractive force
- proportional to the product of the masses
- inversely proportional to the distance between the massive bodies

While Newton presents the three law in a couple of pages, he takes a long time to present his notion of universal gravitation. This is because there lies the true revolution: the idea that *a single kind of force applies to the entire universe.* Newton's biggest revolutionary move is to say that the heavenly bodies and the rocks in the river are made of the same stuff. Celestial and Terrestrial physics are not two different theories, dealing with two very different domains: the two domains are *unified* as governed by a single, *universal* theory. This is the first great unification in the history of physics.

Cf. in the Text: In the Preface to the first edition, Newton rejects that idea that mechanics and geometry are two different domains. Instead: rational, universal mechanics encompasses all domains of natural philosophy (physics). There is no fundamental difference between mechanics (being imperfect) and cosmology (being perfect): the perfect mathematical laws apply everywhere.

Newton's Revolution – a new worldview

	Aristotle	Newton
Fundamental Constituents	Elements, Matter and Form	Massive bodies – Atoms
Interactions	Internal Tendencies	External Forces
Universe	Closed Biological Organism	Huge Machine
Explanations	Teleological	Mechanistic
God	Pilot in his ship	Watchmaker
Society	Natural Hierarchy	Individuals all equals

9.4 Newton, Gravity, Causes and Occult qualities

The notion of Gravity is very difficult to swallow

A mysterious action at a distance –

- In general: we understand action by contact, and we are dubious concerning any notion of action at a distance – a Dewiit says "[action at a distance] sounds like magic"

  Dewitt's example: pen falls by attraction to the Earth / pens and rubber band

- If taken realistically, gravity seems to be a case of a mysterious action at a distance

- Descartes' and Leibniz' criticism: the notion of gravity get us back in time: regression to Aristotle-like explanation in term of *occult qualities* – instead of quantitative mechanical interactions

- The ways the problem was solved after Newton: Local Fields and then Einstein's curvature of space.

- Newton's answer: Instrumentalist attitude towards gravity?

No need for causes? – p. 138, 152

- Newton seems to advocate to remain *agnostic* concerning the reality of gravity.

  Agnostic : literally, without any particular belief – that is, avoiding to take any stance, one side or the other. Suspension of judgment.

- Newton admits that there must be a "true cause", but denies that he has to find out what it is in order to have a satisfactory physical theory

- If true, Newton's physics gives an account of HOW things behave at the observational level, without giving an explanation of WHY they behave this way.

  Does it mean that Newton takes an instrumentalist attitude towards gravity???

⟶ *In defending his theory of gravity in this way, Newton is in fact proposing a new method for science. This is the famous "I frame no hypothesis"*

9.5 Newton's Scientific Method

Reminder – The debate over scientific method:

- Inductivism – Bacon – non practicable

- Hypotheses and Deductions – Galileo and Descartes : For Galileo and Descartes, proper scientific method consists in designing rational hypotheses, deduce what the phenomena should be like from these hypotheses, and check with experiments if needed.

Newton – "I frame no hypotheses"

For Newton, experiments must motivate all the mathematical principles. Newton distinguishes between *hypotheses* and *experimental laws*.

- Hypotheses: principles from which one can maybe deduce the phenomena, but with no empirical support

- Experimental laws: motivated by experience. Conjecture laws from the phenomena, conjecture a simple cause, and make sure that the cause can account for a large range of phenomena. One should not multiply experimental laws: they have to account for a large amount of phenomena to be accepted.

Even if you find a law which gives an account of a very large account of phenomena, it is not necessary to look for a fundamental cause.

Paradigmatic example: Newton deduces the law of gravity from the law of gravitational interactions and not the opposite !

9.6 Newton, Absolute Space and Motion

Absolute vs. Relative spaces – Newton vs. Leibniz

- Relative space: the one that we measure – coordinate systems – they are moving with respect to another

But relative to what?

- Absolute space: ultimate reference for the definition of movement – immutable and immovable

- Absolute space: logically necessary for the validity of the first law : we need to be able to distinguish between uniform motion and accelerated motion. If there is no absolute space, then no difference between the two (in some reference frame, accelerated motions are uniform and vice versa)

- Absolute space: insensible, but we can detect the effect : the absolute acceleration of the water in the bucket

$\longrightarrow$ *To what extend is Newton consistent with his own method when he conjectures the existence of absolute space? Isn't this a "hypothesis"?*

Infinite God in an infinite space :

- Nicholas de Cusa (1401-1464) and Giordano Bruno (1548-1600) had developed the idea that an infinite God is only possible in an infinite universe – Their views were not accepted in their own times. That said, when we had other reasons to believe that the universe is huge, their views made the news more palatable.

- Space and the Sensorium Dei – God constitutes space and time and exists substancially.

9.7 Newtonian worldview after Newton

From 1700 to 1900: "Newtonization" of all domains of science

Chemistry – from quality to quantity

Before 1600 – chemistry is qualitative. Origins in Alchemy. Importance of colors for example

Antoine Lavoisier (1743-1794) – the Chemical Revolution

- Before Lavoisier: Stahl's theory of the phlogiston : combustion = release of phlogiston concealed in all massive bodies – immensely successful
- A major problem: bodies' mass increases with combustion...
- Lavoisier (1772): revolutionary idea: combustion = combination with "oxygen". New method: quantitative approach: use of weight balance + conservation of matter and idea of chemical equation.

Dalton (1766-1844) – Atomism in the theory of gaz

- atoms and repulsive forces
- idea of atomic weight (convention H = 1)

→ *Unification of the chemical and the physical domains: made of the same kind of stuff (atoms), interacting in the same kind of way (external forces), governed by quantitative laws.* Chemistry and physics are not different disciplines anymore, but different levels of investigation of a unified universe.

Biology – reduction to physics

Before 1600 – Vitalism

- Bio-logy = study of life
- living things were considered as being a very *different kind of stuff* from non-living things – a plant does not seem to behave the way a rock does. No reason to suppose either that they are made of the same stuff, or that they are governed by the same laws.

⟶ *Belief in the specificity of life as a phenomenon which cannot be understood solely in physical terms.*

Galvani (1737-1798) and Volta (1745-1827) – Biological Mechanism

Example of the nerves:

- Before: nerves = channel for the vital force / fluid
- Galvani and Volta: nerve conduction is nothing but an electrical phenomenon (frogs' legs)
Other example: organic compound produced from inorganic compounds: no fundamental difference

$\longrightarrow$ *The domains of Biology and Physics are unified: same kind of stuff, same kind of interactions, same kind of laws.*

$\longrightarrow$ *By the early 20th century, Physics, Chemistry and Biology are viewed as investigating the same Newtonian world, though at different levels.*

Electromagnetism – Another great unification

Before 1700 – electricity and magnetism are two different kinds of phenomenon

Franklin (1706-1790) – lightning = electricity

Coulomb (1736-1806) – inverse square law (=Newton-like) for electricity and magnetism

Faraday (1791-1867) – notion of magnetic field, influence of magnetic fields on ligth, Induction, i.e. production of electricity from a magnetic field

James Clerk Maxwell (1831-1879) – Famous equations, governing light, electricity and magnetism.

$\longrightarrow$ *Another, but very important case of unification: electricity, light and magnetism are the effect of the same king of stuff governed by the same kinds of laws.*

9.8 Conclusion

Extraordinary period of scientific success – Two centuries during which

- Everything seems to fall in place in the new Newtonian Worldview
- Every domain of science seems to make huge progress
- Application of the sciences: Industrial Revolution, the beginning of technology
- Scientific Positivism: the march of science = indefinite, cumulative progress toward the truth
- Reductionism: every phenomenon is reducible to particles interacting causally in space and time

Minor Clouds – Lord Kelvin, 1900

Michelson and Morley – Theory of Ether (yes, it's back!)
- Ether: required medium for propagation of light/magnetic/electrical waves
- The experiment: measuring the movement of light in the ether
- The result: no difference

Ouch – minor cloud ? $\longrightarrow$ Relativity Theory

Black body radiation – ultraviolet catastrophe

- Black body – ideal object which absorbs all electromagnetic radiation received
- Heated bodies radiate (coil burner on your stove)
- Equations for black body radiation when heated: the predictions do not match the data in the shorter wave length

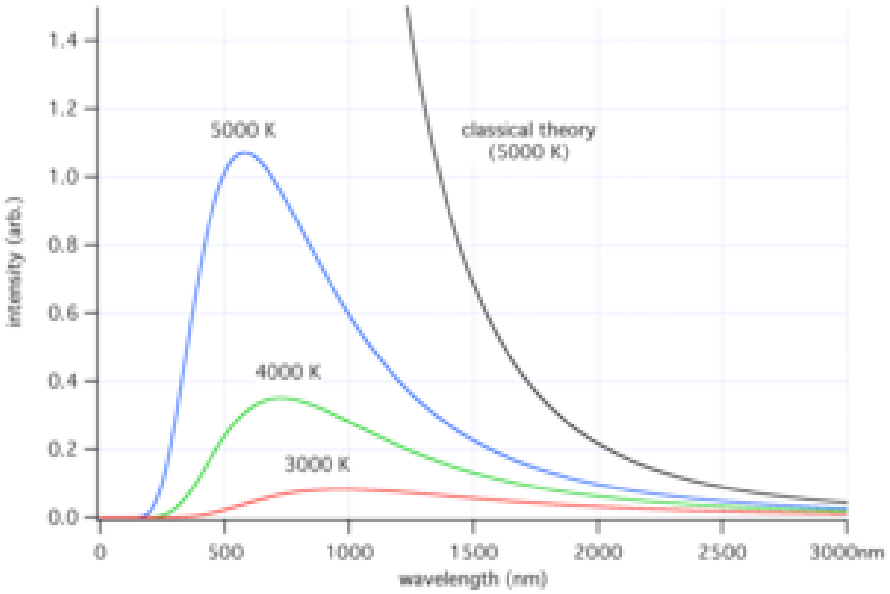

Figure 9.1: Blackbody Radiation: The classical theory in turmoil

Ouch – minor cloud ? $\longrightarrow$ Quantum Theory

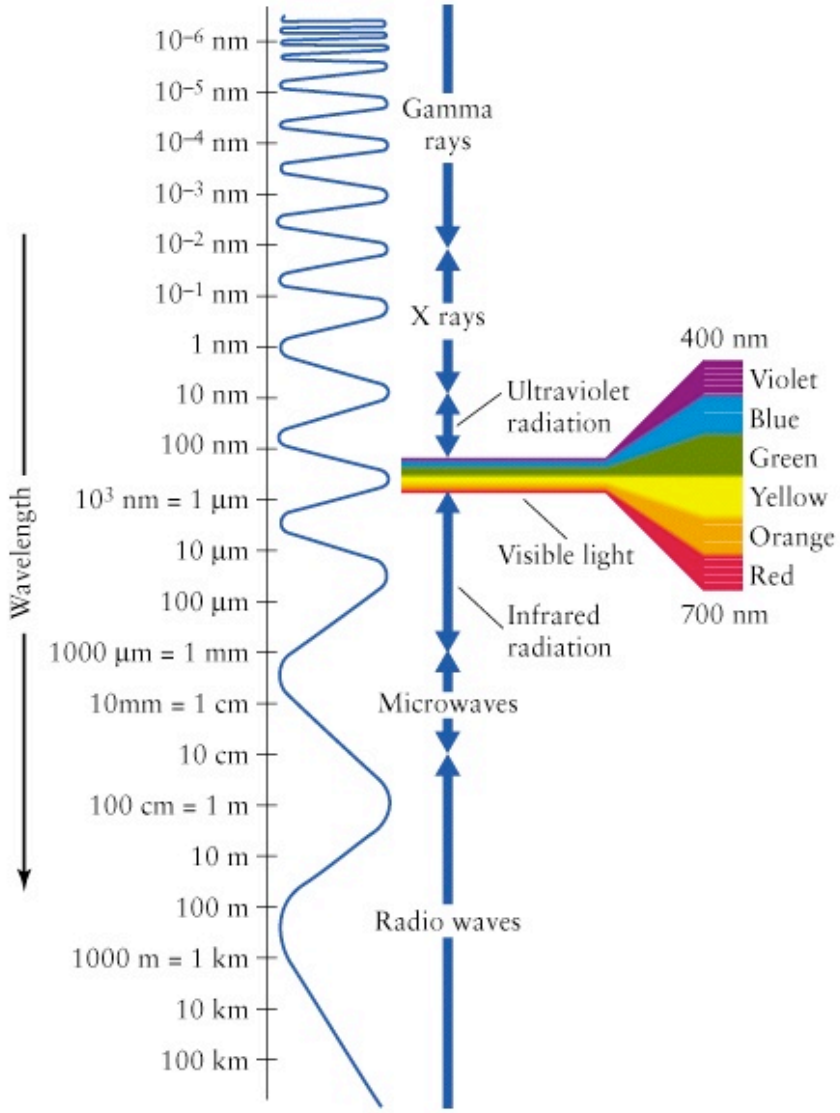

Figure 9.2: Colors and Wavelength