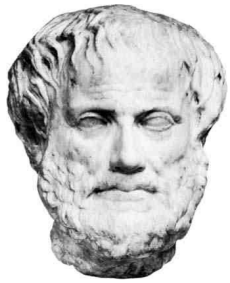
05. Aristotle (4th century B.C.)

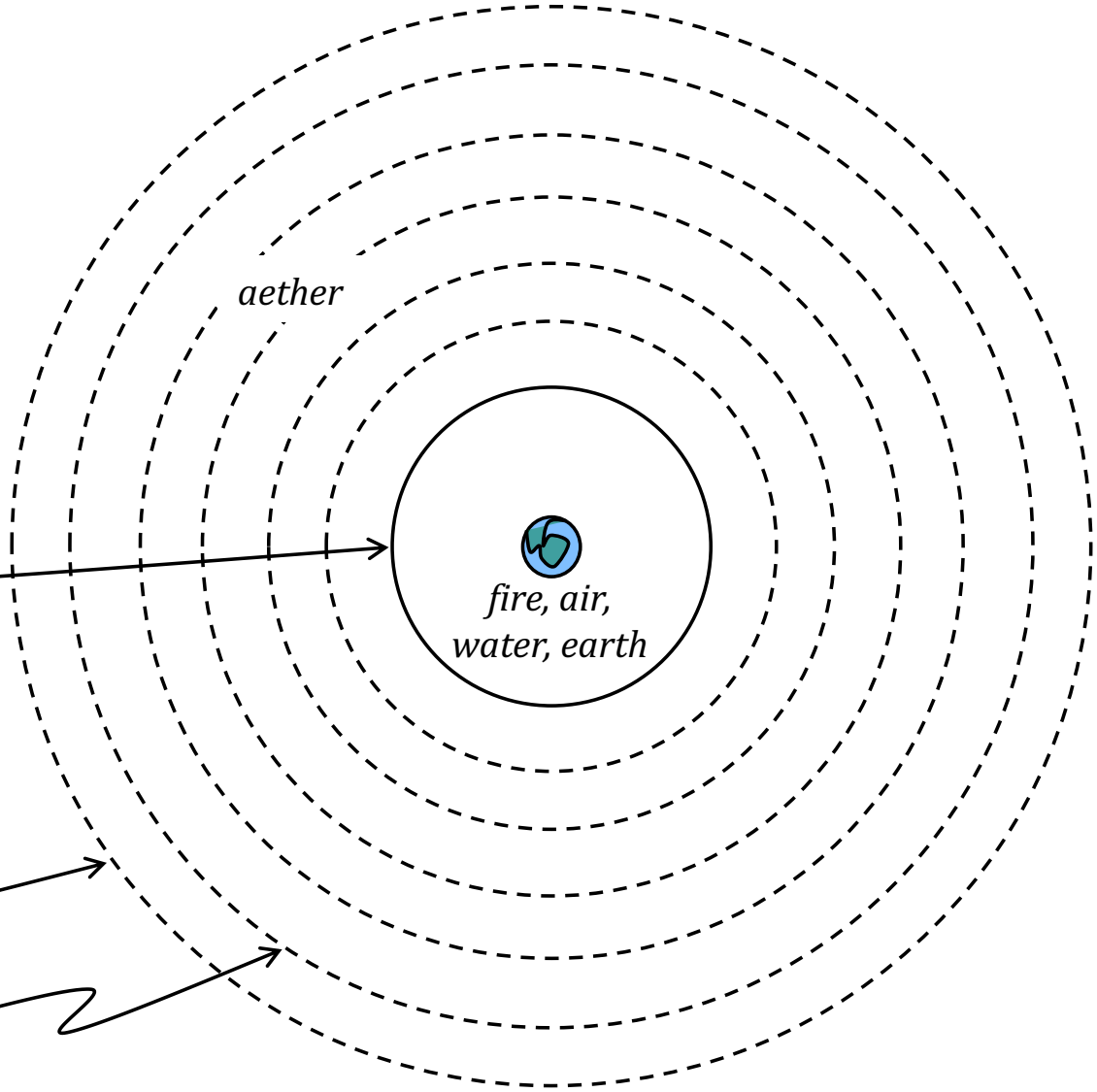
1. The Cosmos
2. Theory of Motion
3. Theory of Space

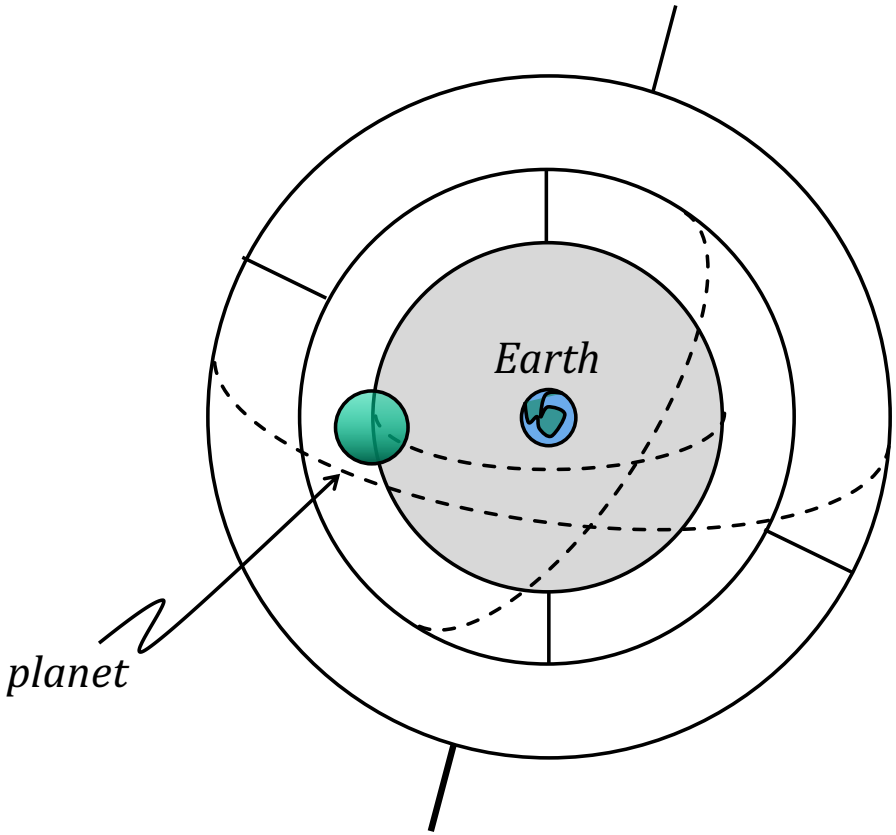


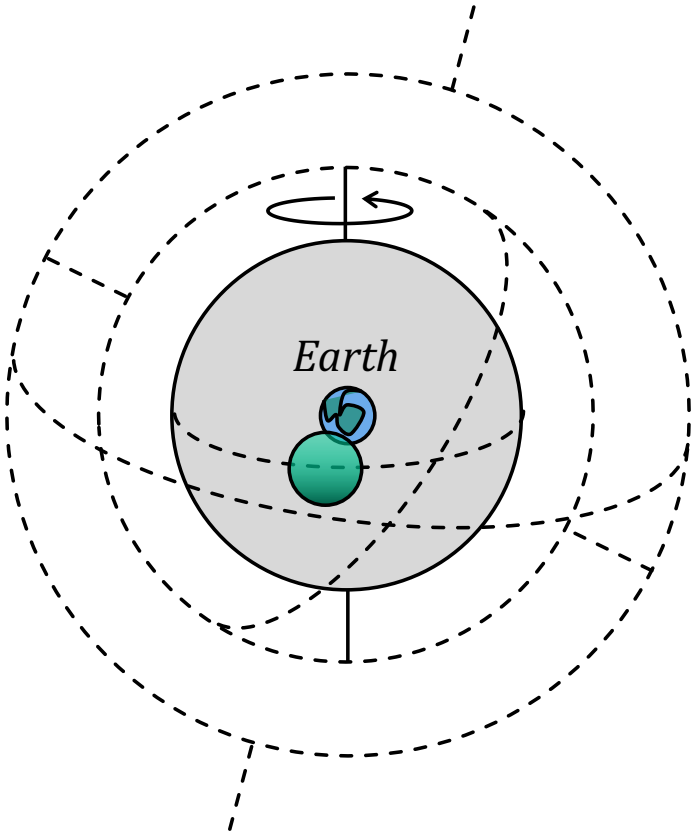
1. The Cosmos

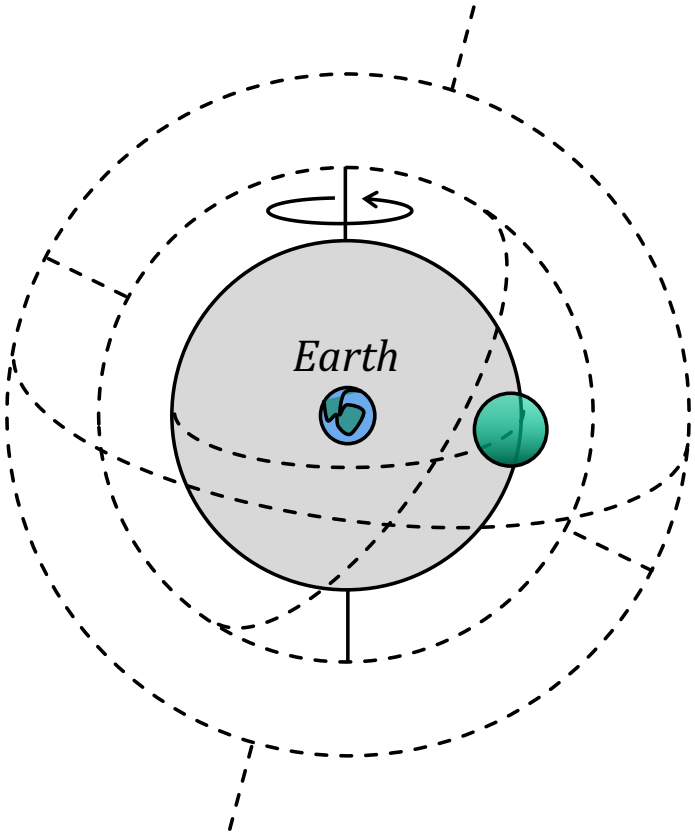
A series of concentric spheres divided into two realms:

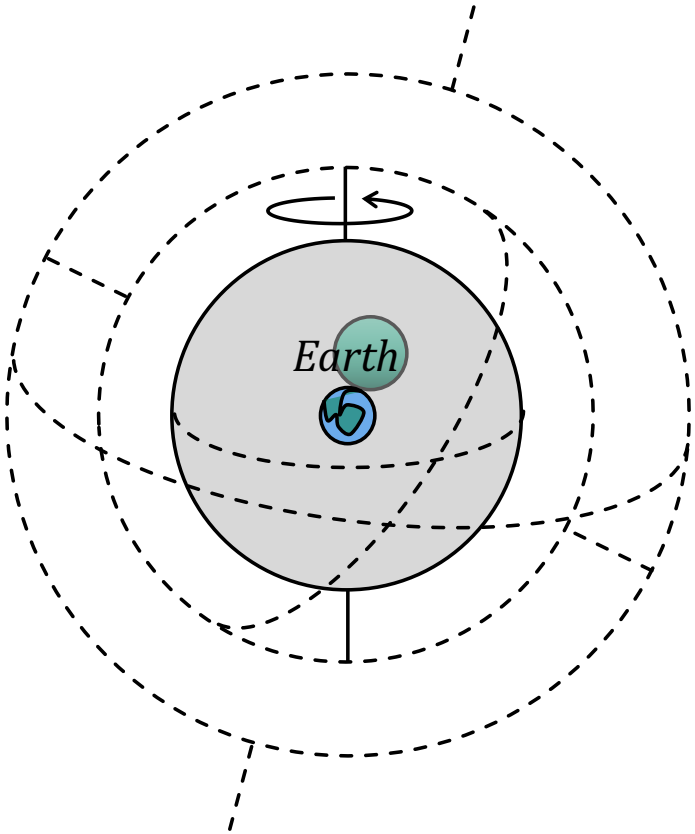
- *The <u>Terestrial Realm</u>*
  Composed of the elements fire, air, water, earth.
- *The <u>Celestial Realm</u>*
  Composed of the element aether.
- *The spheres of the sun and planets. <u>In order:</u>*
  Moon
  Sun
  Venus
  Mercury
  Mars
  Jupiter
  Saturn
  fixed stars
- *Each dotted circle represents a set of nested spheres...*

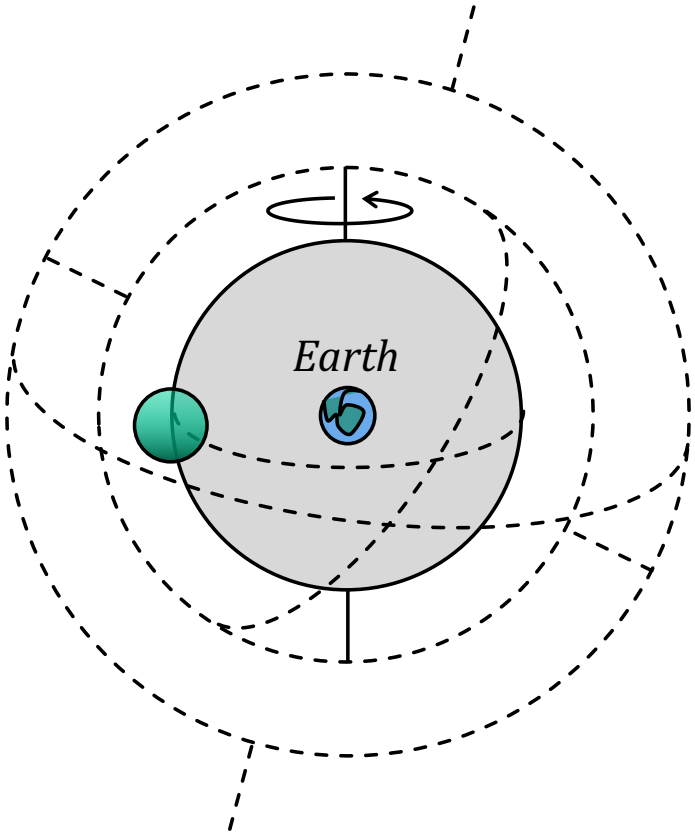


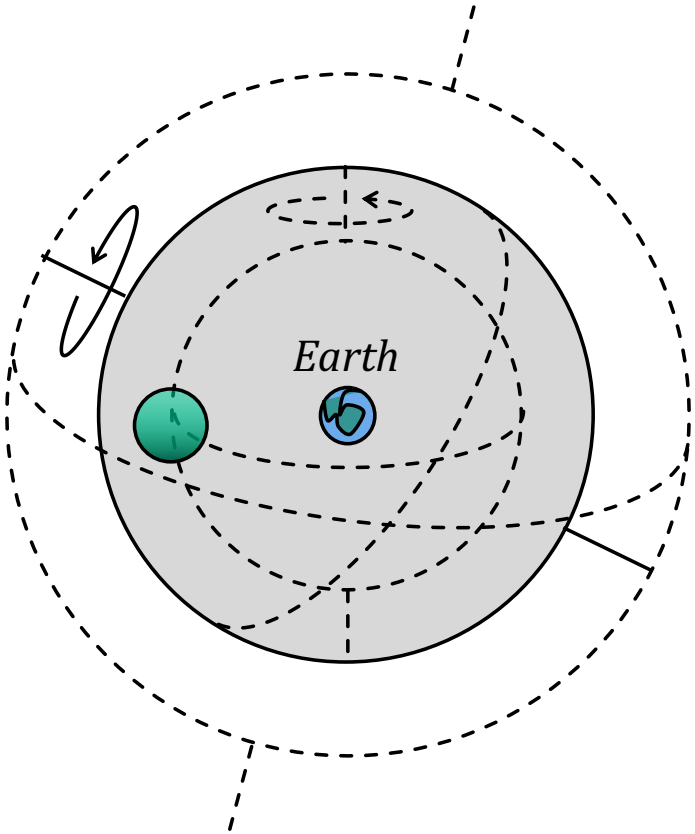

Earth
planet

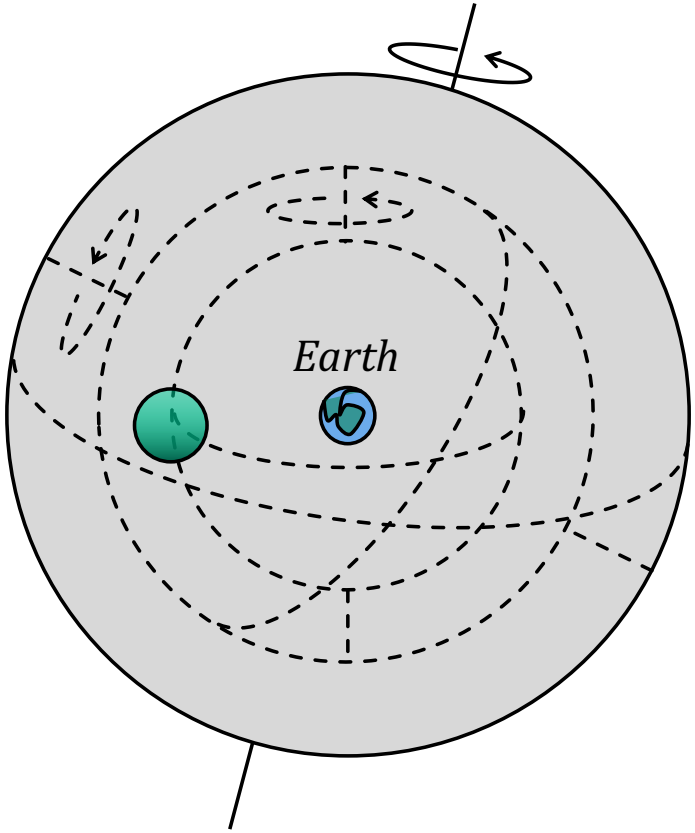

Earth

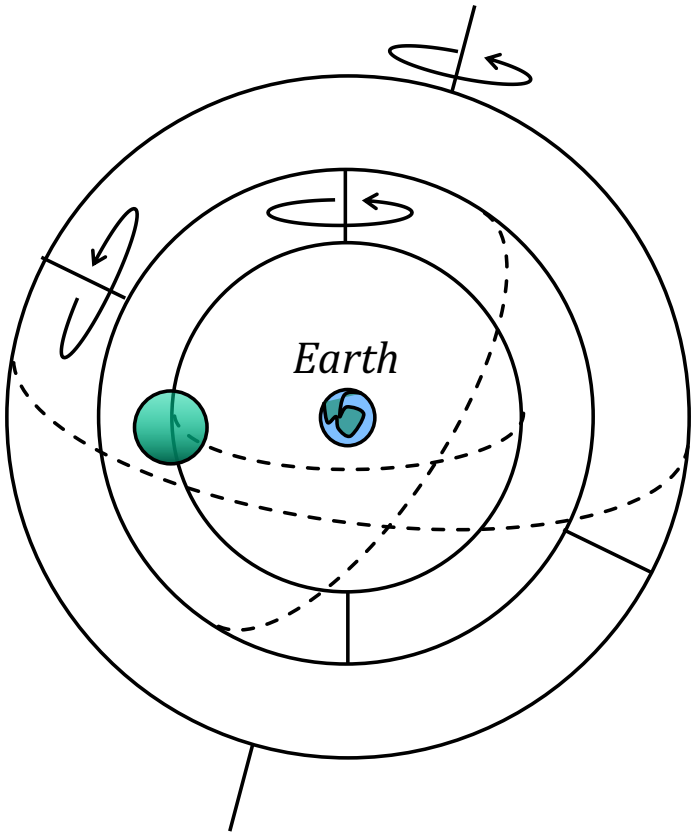

Earth


Earth


Earth


Earth


Earth



How many spheres?

	Eudoxus	Callippus	Aristotle
Moon	3	5	5
Sun	3	5	5 + 4
Venus	4	5	5 + 4
Mercury	4	5	5 + 4
Mars	4	5	5 + 4
Jupiter	4	4	4 + 3
Saturn	4	4	4 + 3
fixed stars	1	1	1
	27	34	56

- Explains retrograde motion.
- Aristotle requires additional spheres to counteract some of the motions of the planetary spheres.
  - *These additional spheres are placed between the outermost sphere of a given planet and the innermost sphere of the next planet and are one less than the number of spheres of the latter.*

2. Theory of Motion

- "Locomotion" = type of change (change of *place*).
  - *Consequence*: *Motion is motion from somewhere to somewhere (finite and bounded).*

- Two basic principles:

> I. *No motion without a mover in contact with moving body.*
>
> II. Distinction between:
>
> (a) *Natural motion*: mover is *internal* to moving body
>
> (b) *Forced motion*: mover is *external* to moving body

Natural Motion

- Mover is the "nature" of the moving body.
- *nature* = an internal goal-directed cause of change.

> - The *nature* of an acorn is to become an oak tree.
> - The *nature* of a planet is to follow a perfect circular path in the heavens.
> - The *nature* of a rock is to fall to the center of the cosmos.

3 Types of Natural Motion and Corresponding Elements

(1)	In *straight line* towards center of the cosmos:	earth, water
(2)	In *straight line* away from center of the cosmos:	fire, air
(3)	In *circle* about center of the cosmos:	aether

How is this different from contemporary accounts?

- Consider Newton's 1st Law of Motion:

  Left unimpeded, a body will continue in a state of rest or in uniform motion in a straight line.

- *Why* does a body do this?
  - Inertia = *tendency* of a body to obey the 1st Law of Motion.
  - The more inertia a body has, the greater its *tendency* to continue at rest or in uniform motion in a straight line.

- Why do bodies have inertia?
  - *No explanation within contemporary physics.*

Doctrine of the Plenum

- *Claim*: There is no void (*contra* the atomists).
- *Assume*:

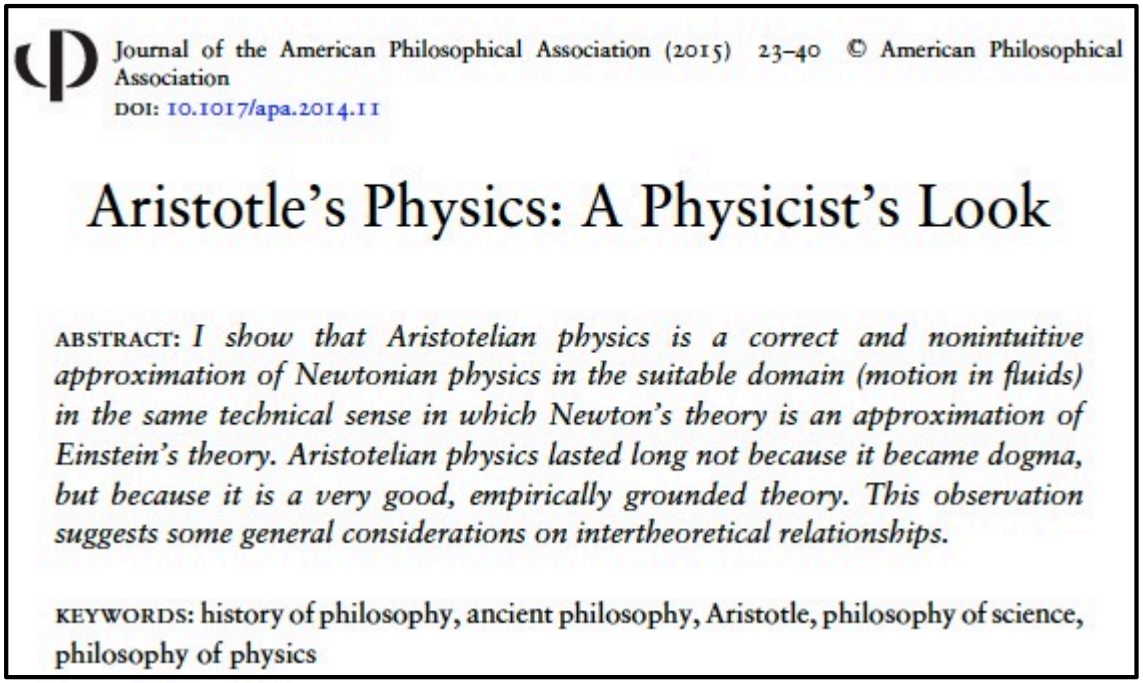
  (i) Speed is inversely proportional to resistence ($V \propto 1/R$).

  (ii) Infinite speed is physically impossible.

- *Conclusion*: Zero resistence is physically impossible.
- *Hence*: There can be no body through which motion can occur that has zero resistence (*i.e.*, zero density; *i.e.*, a void).

- *But*: Could also conclude that Assumption (i) is incorrect.

  - *Zero resistence doesn't necessarily entail infinite speed.*



Journal of the American Philosophical Association (2015) 23–40 © American Philosophical Association
DOI: 10.1017/apa.2014.11

Aristotle's Physics: A Physicist's Look

ABSTRACT: *I show that Aristotelian physics is a correct and nonintuitive approximation of Newtonian physics in the suitable domain (motion in fluids) in the same technical sense in which Newton's theory is an approximation of Einstein's theory. Aristotelian physics lasted long not because it became dogma, but because it is a very good, empirically grounded theory. This observation suggests some general considerations on intertheoretical relationships.*

KEYWORDS: history of philosophy, ancient philosophy, Aristotle, philosophy of science, philosophy of physics

Aside #1: Aristotle on Matter and Form

- All being is in the world.
- Forms exist in sensible objects; *not* in a separate Platonic realm.

Doctrine of Hylomorphism

- A sensible object consists of both *matter* and *form*.
- *Form* determines properties of the object.
  - *Properties cannot exist without a subject in which they adhere*.
- *Matter* provides substratum in which properties adhere.
  - *By itself has no properties (neutral substratum).*
  - *Does not exist without form.*

Aristotle's objection to Plato
There can be no *matter* without *form*, and no *form* without *matter* (with one important exception).

Example
- Gold is yellow, cold, malleable, heavy, smooth, *etc*; determined by its *form*.
- If all these properties could be stripped away, what would remain would be *matter*.

- *Goal of natural inquiry* = To identify the forms of things.
  - *This must start in the sensible world (and not in the realm of reason).*

Aside #2: The Four Causes

1. *Material*:	What is it made of? (That *in which* change occurs.)
2. *Formal*:	What kind of thing is it? (The form *into which* a thing changes.)
3. *Efficient*:	How was it made? (That *by which* change is brought about.)
4. *Final*:	What is it for? (That *for the sake of which* change occurs.)

- Four ways of explaining what makes a thing what it is.
- Operative in both Art (*techne*) and Nature (*physis*).

marble statue of Zeus	*acorn*
1. marble	1. material of acorn
2. shape of Zeus	2. oak tree
3. chisel and hammer	3. rain, sun, soil, nutrients
4. intent of sculptor	4. nature of acorn

- *Note overlaps*: The nature of an acorn is also associated with its form.
  - *In Art, final causes are external/transcendent.*
  - *In Nature, final causes are internal/immanent.*

Is Aristotle deifying Nature with concept of final cause?

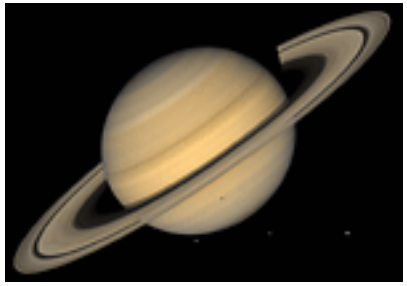
- *No*: Nature does not have an overall purpose.
- *Rather*: Natural processes are internally goal-directed.

Example: Functional explanations in contemporary biology.

- Why are grasshoppers green?
- *Typical answer*: Camouflage is a valuable adaptive trait for grasshoppers.

- But (typically) no explanations of this sort in contemporary physics:

- Why does Saturn have rings?
- *Typical answer*: The rings are the remnant of a moon that broke up in the distant past.



- No appeal to any possible value of having rings for planets.
- Explanations in contemporary physics tend to be framed in terms of *efficient* causes and not *final* causes.
- *Why?*

3. Theory of Space

Two Questions a theory of space must answer

I. What kind of thing is space?

II. How does space interact with bodies?

Suppose space is the collection of all "places" of bodies.

Three Conditions of Adequacy for a concept of "place":

(a) *A place must be separate from the body it contains.*

- *Why?* Different bodies can occupy the same place at different times!

(b) *Places don't themselves have places.*

- *Why?* If they did, then there would be actual infinities in the world: places of places of places of places, *etc*., ...

(c) *The relations of up and down between places are absolute*.

- *Why?* The center of the cosmos defines absolute notions of up and down.

Candidates for a concept of "place"

(1) *The place of a body is the body's shape.*

- The shape of a body = the outer surface of the body.
- *But*: The surface of a body is not separate from it: **Violation of Adequacy Condition (a)!**

(2) *The place of a body is the body's matter.*

- A body consists of matter and form (doctrince of hylomorphism).
- *But*: Matter is inseparable from form (with one exception).
- *So*: The matter of a body is not separate from it: **Violation of Adequacy Condition (a)!**

(3) *The place of a body is the extension between the body's extremities.*

- The *extension* of a body = its volume.
- The *extremities* of a body = the inner surface of the body that contains it.
- A vacuum is impossible, so every body must be contained by another.
- *But*: Volumes are contained in volumes: **Violation of Condition (b)!**

(4) *The place of a body is the body's extremity.*

- The *extremity* of a body = "[the] boundary of the containing body at which it is in contact with the contained body".
- *Which means*: The place of a body, as its extremity, is a 2-dimensional surface (*i.e.*, the boundary between two 3-dimensional objects).
- A body's extremity is separate from it: **Upholds Adequacy Condition (a)!**
- A body's extremity (as a 2-dim surface) does not itself have an extremity: **Upholds Adequacy Condition (b)!**

- *But*: If motion is change of place, then the place of a body must be motionless with respect to it.
- *So*:

> A body's place is "the innermost motionless boundary of what contains [it]".

Significance of Adequacy Condition (c)

(c) *The relations of up and down between places are absolute*.

- *Modern gloss:*

  The cosmos defines an absolute frame of reference ("motionless place") with respect to which up and down can be defined unambiguously.

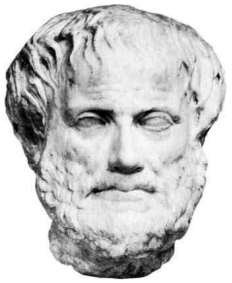
- Aristotle's cosmos has *natural places* for its objects:

element	*natural place*
earth	center
water	center
air	below lunar sphere
fire	below lunar sphere
aether	celestial realm

- The natural places dictate the natural motions: natural objects move by nature to their natural places.

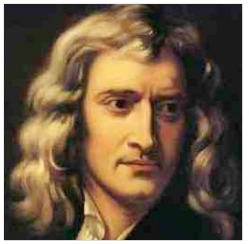
Comparisons

Aristotle's Absolute Frame



- Defined by physical objects.
- Non-isotropic (privileged directions of up and down).
- Non-homogeneous (privileged position = center).
- Rotational symmetry (no privileged orientation about the center).

Newton's Absolute Frame



- Independent of physical objects.
- Isotropic and homogeneous (no privileged directions or positions).
- Translational and rotational symmetry.

Useful Distinction Introduced by Aristotle:

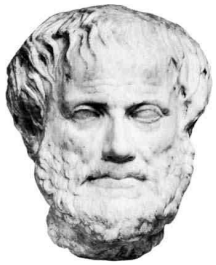
(i) Kinematics = motion in the absence of forces ("natural" motion).

(ii) Dynamics = motion in the presence of forces ("forced" motion).

- Theories of motion may differ on how they make this distinction.

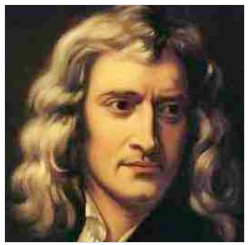
Example 1:

- *Aristotle's kinematics*:



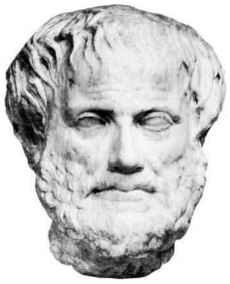
- *finite motion away from center.*
- *finite motion toward center.*
- *finite motion about center.*

- *Newton's kinematics*:

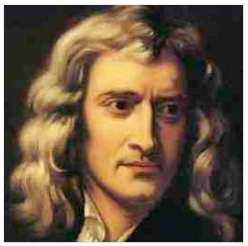


constant, rectilinear, unbounded motion.

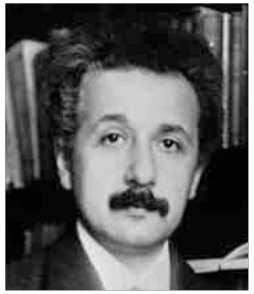
Example 2: Motion of freely-falling objects.



natural/kinematical (motion due to nature of object).



forced motion/dynamical (motion due to gravitational force).



natural/kinematical (motion in the absence of a force).