

IPM component 3



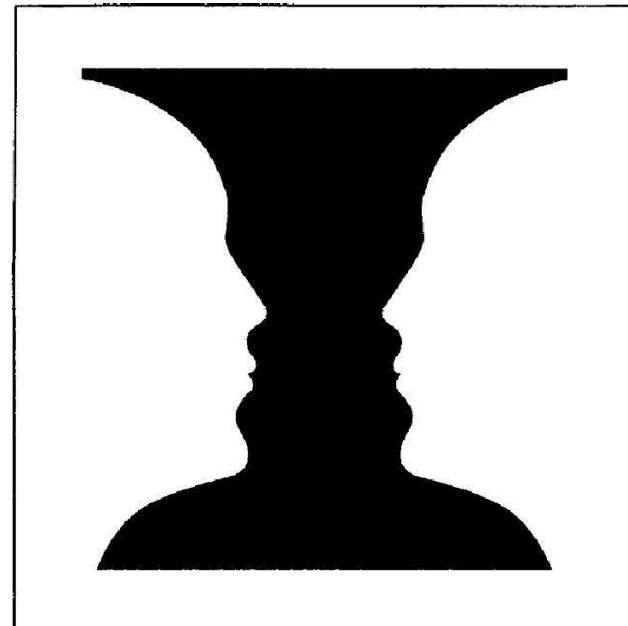
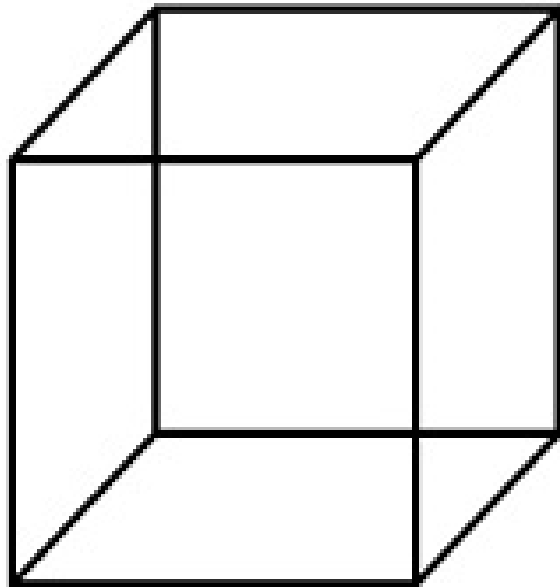
Term 1, week 6

**On ways of thinking
and scientific paradigms**

Ways of thinking/perceiving

Exercise 1: Perception of images

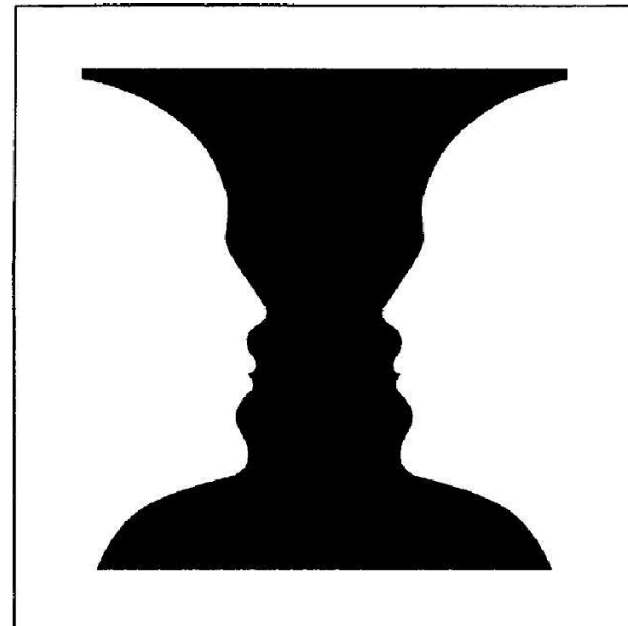
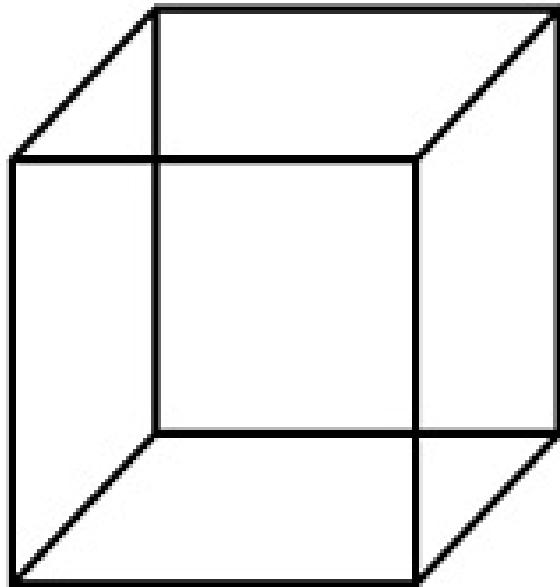
- Look at the images below.



Ways of thinking/perceiving

Exercise 1: Perception of images

- Can you see the two different perspectives of each image?

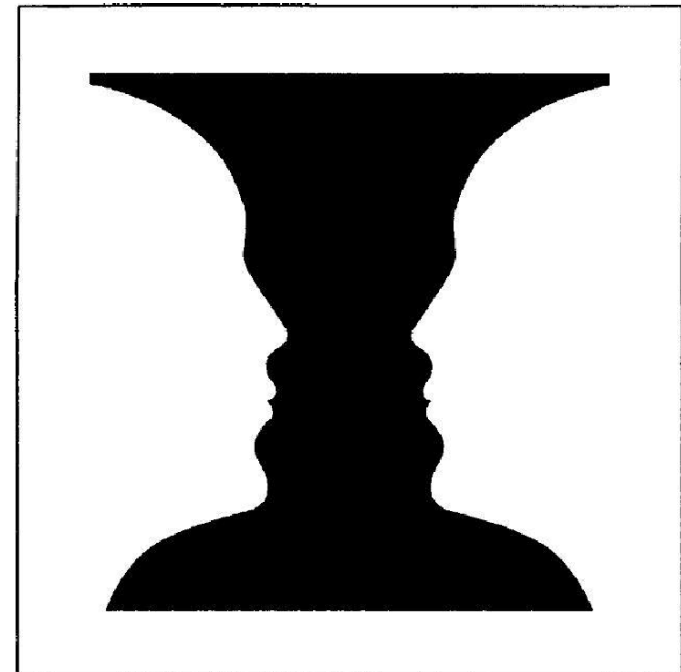


Ways of thinking/perceiving

Exercise 1: Perception of images

Two ways of thinking:

- Worldview 1: Two white faces looking at each other;
- Worldview 2: A black vase.



Ways of thinking/perceiving



Exercise 2: Water

- Perceiving the nature of water to be

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Ways of thinking/perceiving



Exercise 2: Water

- My guess is that the suggestions you made about were all descriptions of effects.
- Can we only know about water via its effects, i.e. by what it does and how it behaves?
- Do these effects really describe the nature of water in itself?

Ways of thinking/perceiving



Example 1: Physics

- For physics we have had different worldviews about
 - Gravity: Newton version

Gravity is a force which acts at a distance. The force seems to act spontaneously with no medium to transmit this force across space.

Ways of thinking/perceiving



Example 1: Physics

- For physics we have had different worldviews about

- Gravity: Einstein version

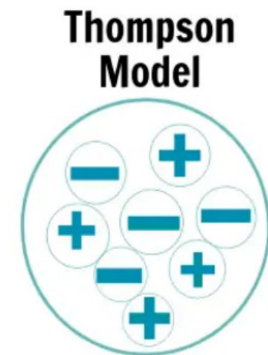
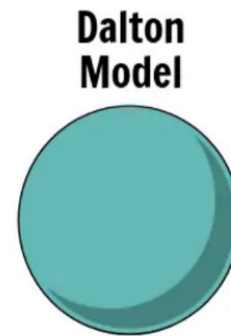
Gravity is not a force but curved spacetime. Masses such as planets cause space to be curved. This curvature causes things (like planets) to move.

Ways of thinking/perceiving

Example 1: Physics

- For physics we have had different worldviews about
 - Mechanics: Classical mechanics

Atoms, p^+ , e^- and n are the smallest units of matter, and are solid objects in fixed positions or orbits.

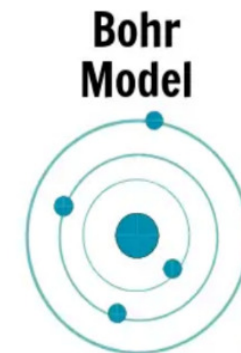
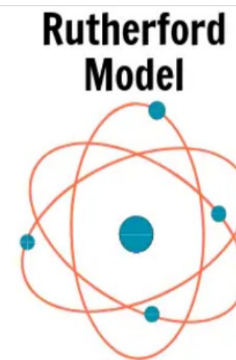


Ways of thinking/perceiving

Example 1: Physics

- For physics we have had different worldviews about
 - Mechanics: Classical mechanics

Atoms, p^+ , e^- and n are the smallest units of matter, and are solid objects in fixed positions or orbits.

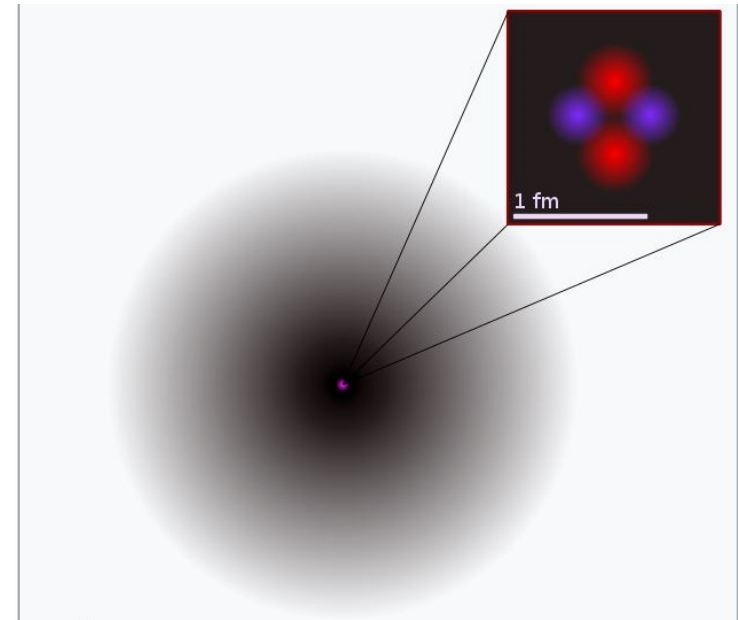


Ways of thinking/perceiving

Example 1: Physics

- For physics we have had different worldviews about
 - Mechanics: Quantum

p^+ , e^- and n are not the smallest units of matter; e^- are not in fixed orbits, but are distributed probabilistically to form clouds.



Ways of thinking/perceiving



Example 1: Physics

- For physics we have had different worldviews about
 - Light: Particle vs wave theory
 - Newton found by experiment that light was made of particles;
 - Thomas Young found light to be a wave form;

Ways of thinking/perceiving



Example 1: Physics

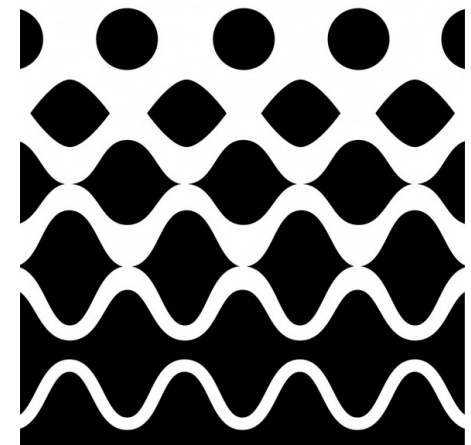
- For physics we have had different worldviews about
 - Light: Particle vs wave theory
 - Quantum mechanics explained that light can be both particle form or wave form;

Ways of thinking/perceiving

Example 5: Physics

- For physics we have had different worldviews about
 - Light: Particle vs wave theory

LIGHT IS A
WAVE!



Ways of thinking/perceiving



Example 2: The paradigm of geometry

- From Euclid (4th to 3rd century BC) up to the mid 1800s mathematics was thought to be fundamentally all about geometry.
- Numbers, arithmetic, algebra, even calculus existed, but everything had to be translated back into geometry.

Ways of thinking/perceiving



Example 2: The paradigm of geometry

- Any problems solved by algebra had to be solvable by geometry otherwise the algebraic solution was not accepted.
- So, numbers were constructed using geometry; arithmetic (such as addition) was done using geometry;

Ways of thinking/perceiving



Example 2: The paradigm of geometry

- The only valid proof were proofs based on geometry (not algebra or arithmetic), i.e. by the use of rulers and compasses only.
- The tools used to do this were the compass and the ruler;

Ways of thinking/perceiving

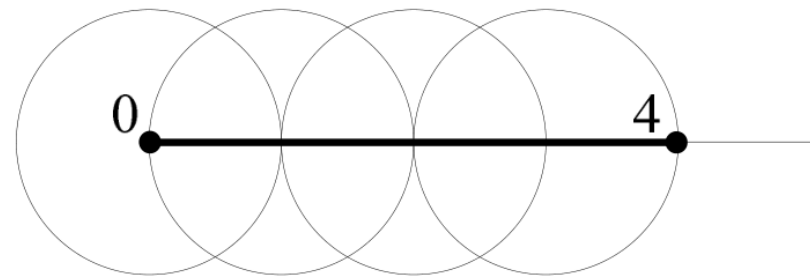
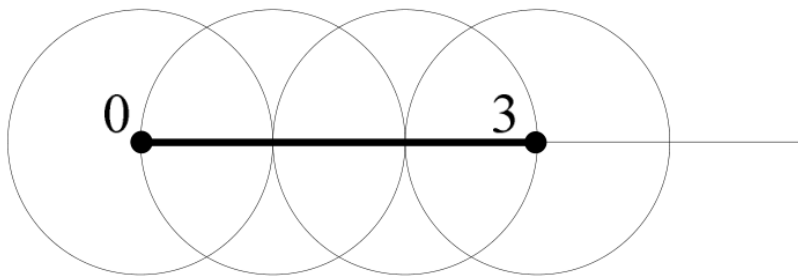
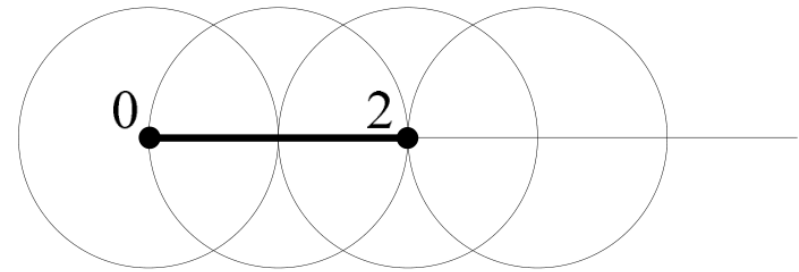
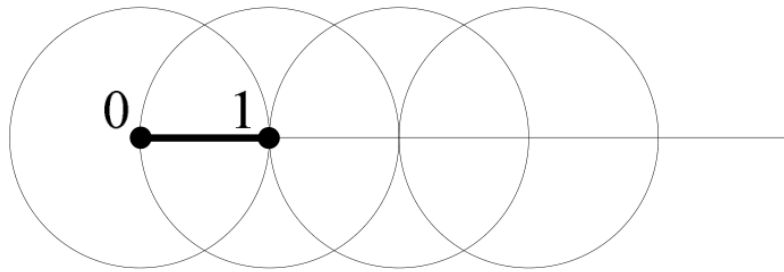


Example 2: The paradigm of geometry

- *Example: constructing the positive integers*
 - Start with two points (as already given to us).
 - Define these to be 0 and 1.
 - Construct other integers as shown below.

Ways of thinking/perceiving

Example 2: The paradigm of geometry



Ways of thinking/perceiving

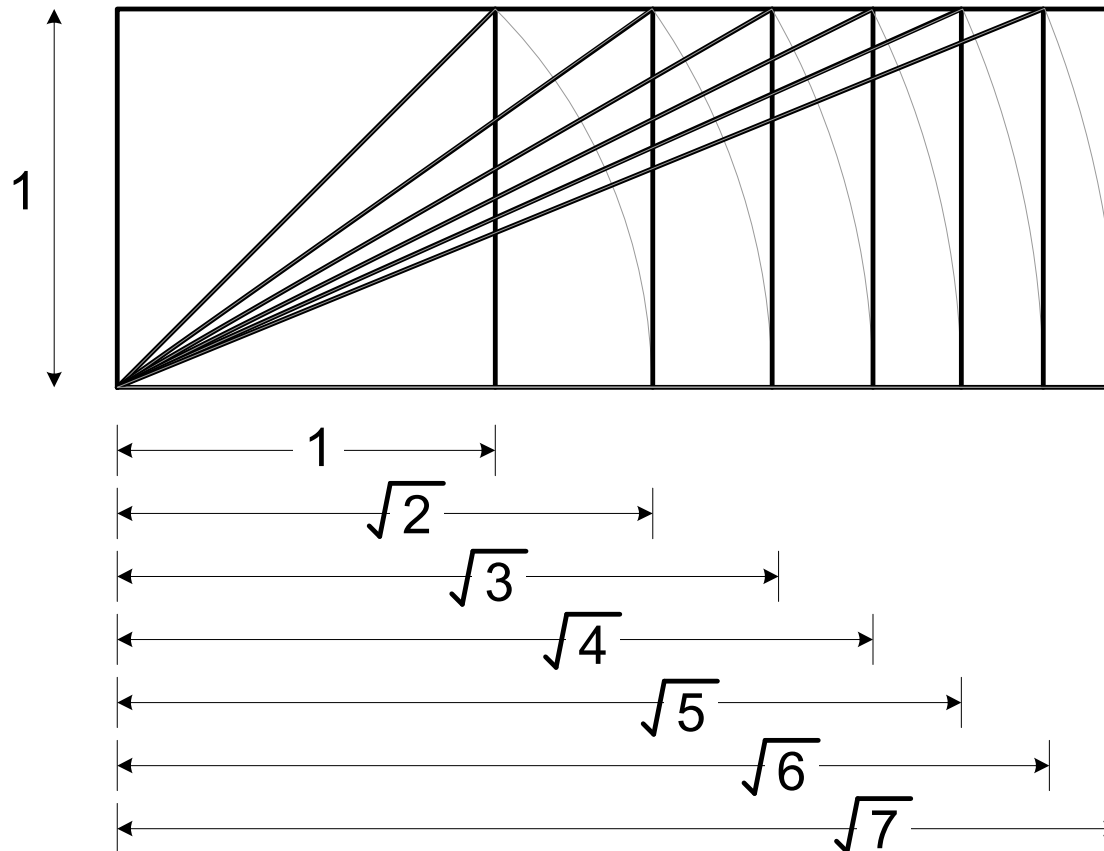


Example 2: The paradigm of geometry

- Fractions could also be constructed geometrically (not shown in the main notes since it is quite involved).
- Square roots of positive integers could also be constructed geometrically using ruler and compass. See next slide.

Ways of thinking/perceiving

Example 2: The paradigm of geometry



Ways of thinking/perceiving



Example 2: The paradigm of geometry

- Additions, subtraction, multiplication and division can also be done by geometry. See main notes for an example of how to perform addition.

Ways of thinking/perceiving



Example 2: The paradigm of geometry

- But confusion started to reign in mathematics from the mid-1800s onwards.
- This was due to the discovery of alternative geometries such as hyperbolic and spherical geometry.
- If we could not rely on geometry could we rely on algebra or number?

Ways of thinking/perceiving



Example 2: The paradigm of geometry

- Initially it seemed not. Problems with algebra and numbers were also found:
 - algebra/arithmetic, where $a \times b \neq b \times a$ (matrices and the vector product),
 - numbers such as quaternions which are 4-dimensional numbers, and which do not obey commutativity.

Ways of thinking/perceiving



Example 2: The paradigm of geometry

- However, a way out was found, and by the end of the 1800s mathematics was re-constructed on the basis of numbers and arithmetic, not geometry.
- So the geometric paradigm of maths has changed to be the arithmetic paradigm.

Ways of thinking/perceiving



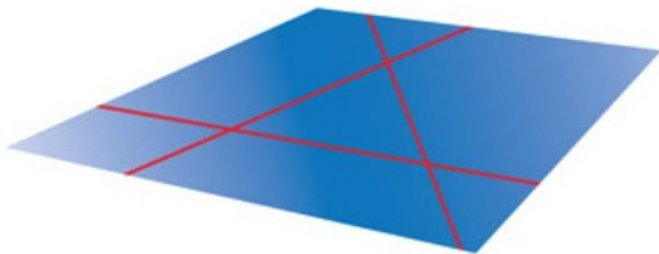
Example 3: The paradigm of Euclidean geometry

- Even geometry itself has its own paradigms.
- Again this was only discovered during the 1800s.
- The three now common paradigms of geometry are ...

Ways of thinking/perceiving

Example 3: The paradigm of Euclidean geometry

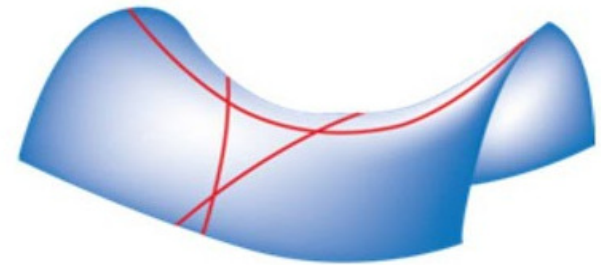
Euclidean
geometry



Spherical
geometry



Hyperbolic
geometry



Ways of thinking/perceiving



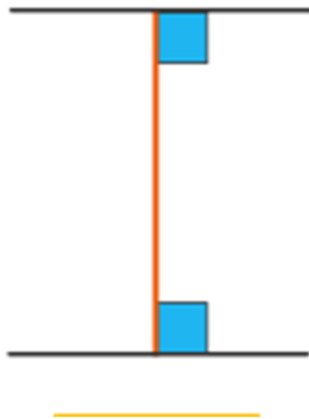
Example 3: The paradigm of Euclidean geometry

Euclidean Geometry	Spherical Geometry	Hyperbolic Geometry
Parallel lines remain parallel	Parallel lines meet	Parallel lines diverge
All angles of a triangle add up to 180°	All angles of a triangle add up to $> 180^{\circ}$	All angles of a triangle add up to $< 180^{\circ}$

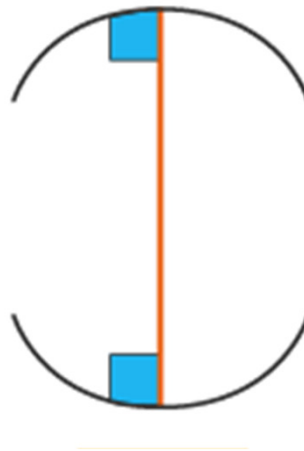
Ways of thinking/perceiving

Example 3: The paradigm of Euclidean geometry

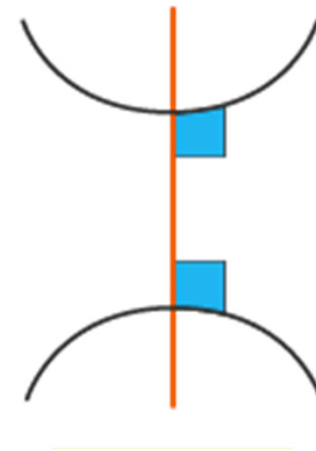
Euclidean
Geometry



Spherical
Geometry



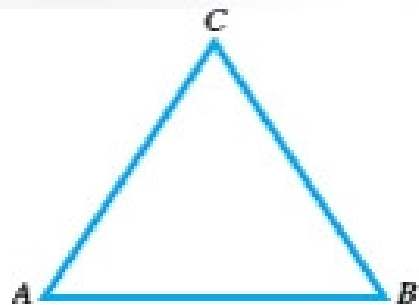
Hyperbolic
Geometry



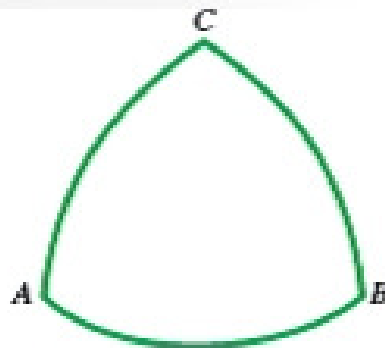
Ways of thinking/perceiving

Example 3: The paradigm of Euclidean geometry

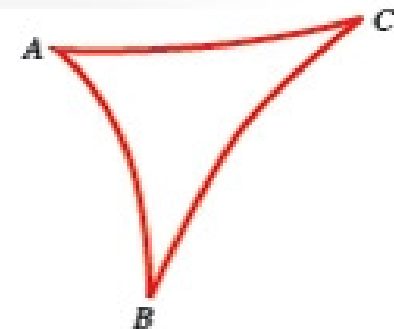
Euclidean
Geometry



Spherical
Geometry



Hyperbolic
Geometry



Paradigms



Definition

- A paradigm is a set of beliefs, a perspective, a worldview that dominates our thinking about the way nature works and how we can study nature scientifically.
- Paradigm consist of core beliefs which “cannot” be changed, and peripheral beliefs which are open to debate.

Paradigms



Definition

- Paradigm thinking can become very rigid or entrenched, and can last for decades or centuries.

Paradigms



Examples

- Newtonian theory of gravity was a paradigm.
- Einstein's theory of relativity was a radically different paradigm about how to think about, perceive and work with, gravity.

Paradigms



Examples

- The model of the atom as
 - indivisible

then

- composed only of electrons, protons and neutrons, these being solid objects in fixed positions or orbits

were two paradigms.

Paradigms



Examples

- A third, and current, paradigm is that the atom
 - is composed of hundreds of different types of subatomic particles,
 - has electrons are distributed probabilistically as a cloud around the nucleus.

Paradigms



Examples

- The following model was a paradigm:
 - the sun and planets revolved around the Earth which was at the centre of the system;
 - everything revolved around the Earth in circular orbits;
 - the stars were fixed and never moved

Paradigms



Examples

- The following model is a paradigm:
 - All planets revolved around the sun which is at the centre of the system;
 - everything revolved around the sun in elliptical orbits;
 - the stars are not fixed but move across the galaxy. The solar system revolved about the centre of the galaxy.

Paradigms and anomalies

- The geocentric system cannot explain the motion of Mars.

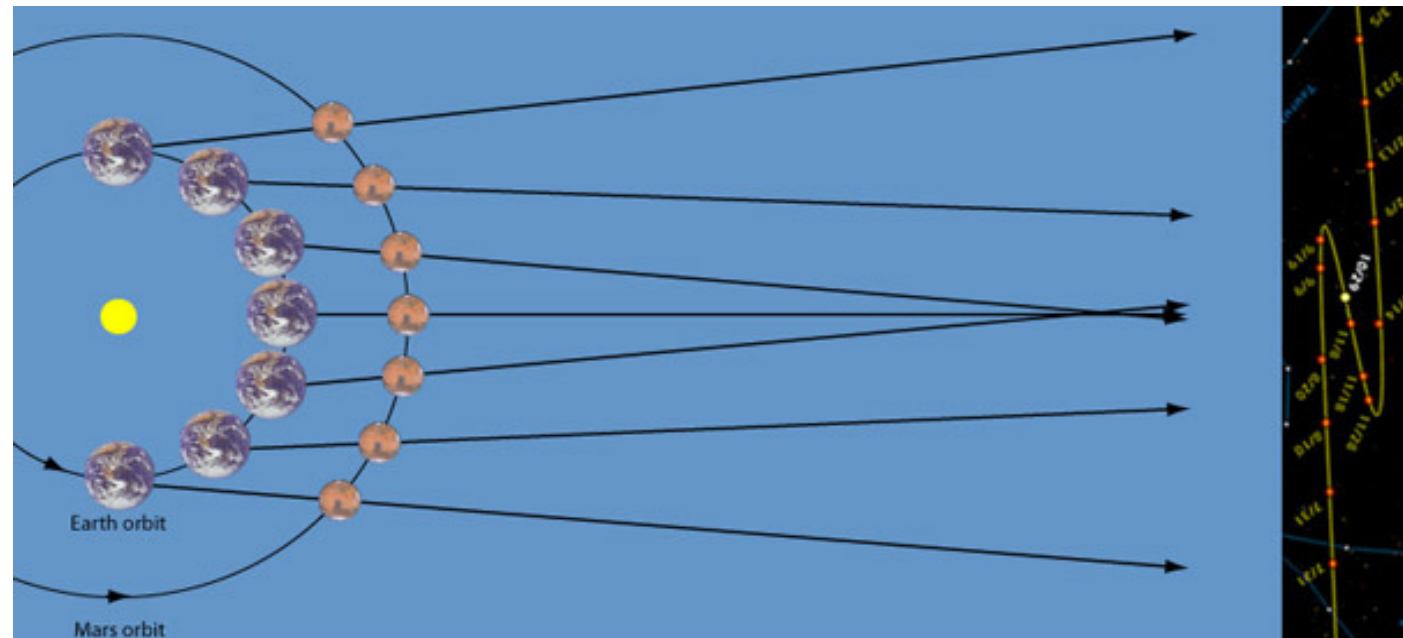
Retrograde motion of Mars:
Mars' motion backtracks for
a couple of weeks every two
years.



Paradigms and anomalies

- The geocentric system cannot explain the motion of Mars.

Retrograde motion of Mars: This can only be explained if the Earth orbits the Sun.



Paradigms and anomalies



- See notes for the problem of the precession (i.e. rotation) of the orbit of Mercury.

Summary



Discipline	Old paradigm	New paradigm
Astronomy	Geocentric system with circular orbits and fixed stars	Solar system with elliptic orbits and moving stars
Physics	Gravity is a force which acts invisibly at a distance	Gravity is curved spacetime
Mathematics	Mathematics is geometry	Mathematics is number and arithmetic

Summary



Discipline	Old paradigm	New paradigm
Physics	The atom is indivisible	The atom has many particles which themselves have many particles.
Heat	Heat is an inherent quality of a substance.	Heat is energy transfer between two substances

Summary



Discipline	Old paradigm	New paradigm
Chemistry	???	???
Data science	???	???
Thermodynamics	???	???
Aerodynamics	???	???
Hydrostatics	???	???

Paradigms and anomalies



- **Exercise**

- What are the core beliefs/theories accepted by your discipline? What aspect of your discipline can be debated?
- What aspects of your discipline cannot be debated? What is not acceptable to question?

Advantages of paradigms



- Gives a framework for thinking;
- Gives us a theoretical framework on which to more deeply understand natural phenomena;
- Help us develop tools (theoretical and practical) for research;
- Allows us to make predictions.

Disadvantages of paradigms



- We can get stuck in our thinking and worldview for decades or centuries;
- This can stifle alternative thinking and theories;
- Can prevent people speaking out for alternatives.

Disadvantages of paradigms



- Can cause confusion. People in different paradigms think and talk differently:
 - A chemist and a physicist might operate with different paradigms of what a helium atom is.
 - “Solution”:
 - For chemistry it is a combination of substances fully and homogeneously mixed together;
 - For maths it is the complete, step-by-step process of finding the answer to a problem;

Disadvantages of paradigms



- Can cause confusion. People in different paradigms think and talk differently:
 - “Plasma”: For medicine it is part of blood; For physics it is ionized gas;
 - “Mantle”: For geology it is the layer of the earth between the crust and the core; for zoology it is a protective layer of the skin in molluscs that secretes a substance which forms the shell.

Ways of thinking and scientific paradigms



The end