Lecture 1:

Fundamentals of Physics

Phys 120, Fall 2014

The origins of Physics in ancient Greece

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Outline

- Technical preliminaries
- What is Physics?
- A historical perspective
- A matter of perception
- The shift of perception in 5th century Greece

Technical Preliminaries

Book: Physics, Concepts & Connections, Art Hobson.
Other literature: Lindberg: The beginnings of Western Science
Xenophon: Conversations of Socrates
Plato: The collected Dialogues
Aristotle: Physics

Accompanying this lecture there is an online course-management system called LON-CAPA. You should have received an email with instructions, but you can access this from the Physics department homepage. Please contact Paul.Omernik@ndsu.edu with any problems.

There you will find weekly homework as well as posted lecture notes. You will also be able to see the results for your tests here.

TA support: the Physics Department provides support for you:
`http://www.ndsu.edu/physics/current_students/ta_office_hours/`
The homework are last years homework, and are still being reviewed. The exact content will still change. Please let me know if/when you have thoughts and suggestions about the lecture or the homework.

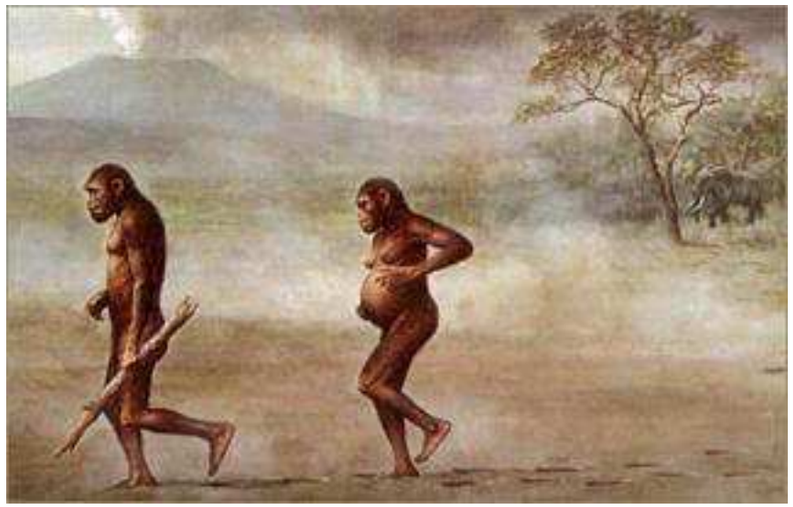
What is Physics?

The name physics comes from Aristotle who understood it to be the study of natural phenomena.

Even before Aristotle there were a number of individuals (mostly in Greece) who raised questions about the nature of our world.

To understand the origins of Physics let us try to put ourselves into the shoes (or bare feet) of humanity before the discovery of Physics.

Speculations on early man



Discovery of numbers: counting sheep with stones (Sumeria)

Development of agriculture causes many new problems:
When should I plant? Prediction of the seasons
How much seed to I need? Measurement of areas and volumes
How much yield can I expect? Measurement of areas
How much should I tax my citizens? Fractions

These considerations lead to **abstractions**.

Astrology

It is obvious that celestial phenomena have significant influence on humanity. The ancients detected a correlation between the path of the sun in the sky and the seasons. The knowledge of these cycles, and the ability to predict them is absolutely crucial for determining when so sow your crops.

The moon is responsible for light in the night, and the phases of the moon and the tides are also closely related to the phases of the moon. Knowledge of the moon phases is crucial for navigation and planning of night raids.

The position of the stars throughout the night can also be used to determine the season, and, with sufficient training, it will tell you the time at night. Again a crucial military advantage.

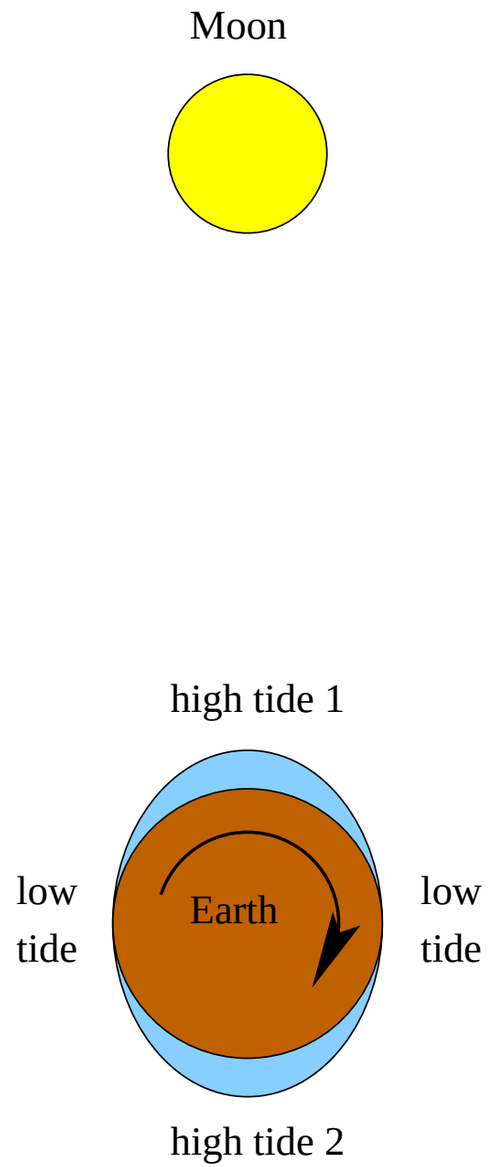
No wonder that it would be thought that special phenomena like solar and lunar eclipses also are important messages from the gods. Likewise there are special stars that wander relative to the fixed firmament, which were called by the Greeks the planets (or wanderers).

Tides

When you are at the coast of an ocean you will observe that the level of water changes periodically. This change gives rise to an important eco-system, the tidal flats and allows for sandbanks that are only above water during low tides.

There are roughly two high tides and two low tides every day, and these tides are correlated with the moon. You can observe that the high tide occurs when the moon is overhead, and again about twelve hours later. This leads to the picture on the right hand side, which gives a graphical display of the observations.

Explaining the reasons for why there are two tidal bulges is rather more difficult, and we will get back to this when we understand gravity and circular motion.



Astronomy

The interest in Astrology was a key driving force in the development of Astronomy. If the solar and lunar eclipses, the position of the planets were important portents of the will of the gods, it was crucial to be able to know more about them. And because of the regularity of the observed cycles there was even a hope of predicting (some of) these phenomena.

Babylonian researchers focused on predicting results by trying to detect patterns. Buoyed by their success the Astrology/Astronomy researchers received a significant amount of funding, which allowed a quite sophisticated set of results.

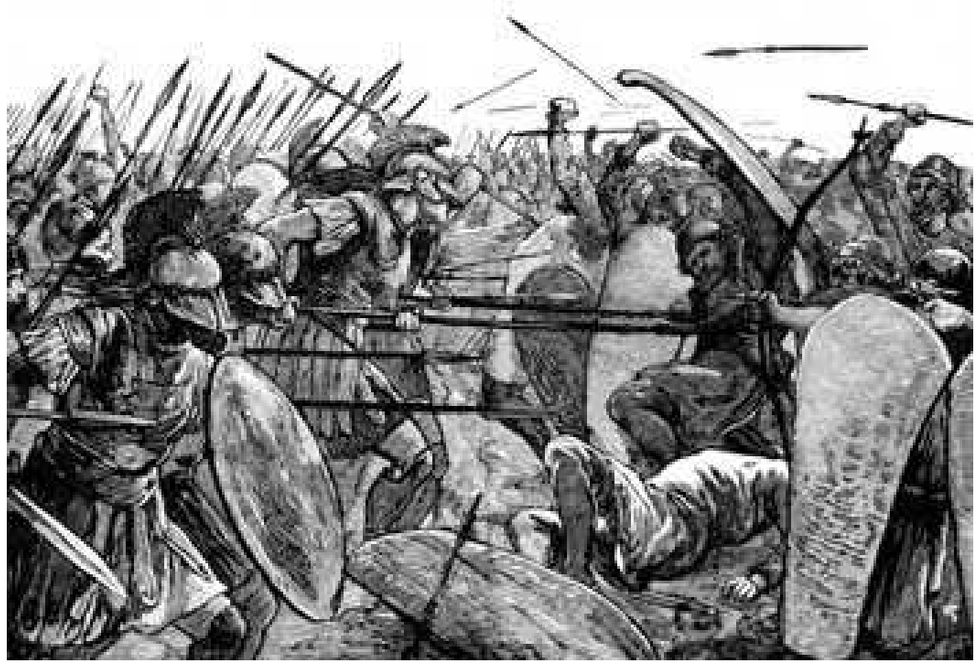
The Greek approach, however, was fundamentally different. Instead of just describing the phenomena they tried to understand them. The idea was that one could devise and abstract **model** of the cosmos, and from such a model one would then be able to predict the observed phenomena.

Strength of faith in ancient Greece

Evidence of the strength of the Greek believe system form the battle of Platea, where the united forces of the remaining Greeks faced the Persian land invasion together with their allied forces.

Before a battle the commander will usually request input from an oracle. In this case the oracle had stated that "they will win the war, but only if they don't attack", and the Persians received a similar oracle.

Before a battle the commanding king of Sparta (there were always two) sacrificed. Soothsayers could detect if the sacrifice was successful by investigating the liver of the victim: if it has a lobe, the sacrifice has been accepted by the god, otherwise it was rejected.



The sacrifice was unsuccessful and the Spartans huddled beneath their shields and fell as the Persian cavalry and light troops attacked. Only after several attempts was the sacrifice successful and the Spartans eventually succeeded in defeating the Persians.

Bad Omens

Plutarch writes about Nicias' (Athenian general) attempted retreat from Syracuse (July 413 BC):

But at the very moment when all the preparations were complete and the enemy, not suspecting any move of this kind, were off their guard, there occurred a nocturnal eclipse of the moon. This terrified Nicias and those of his men who were sufficiently ignorant or superstitious to be disturbed by such a sight. Eclipses of the sun towards the end of the month were by this time understood even by the uneducated to be caused in some way or other by the shadow of the moon. But in the case of the moon, what it could be that crossed her path and caused her while she was full to lose her light and give off so many different colors, they found far more difficult to explain. They were convinced that it must be a supernatural portent and a warning from the gods that fearful calamities were at hand.

The first man to attempt to explain in writing the illumination and eclipse of the moon was Anaxagoras, and his account was the boldest and most lucid of all. But this was a recent theory, nor did it enjoy much repute: in fact, it was still treated as a secret, confined to a small circle and only communicated with great caution rather than with confidence. Public opinion was instinctively hostile towards natural philosophers and visionaries, as they were called, since it was generally believed that they belittled the power of the gods by explaining it away as nothing more than the operation of irrational causes and blind forces acting by necessity.

For this reason even Protagoras was driven into exile and Anaxagoras imprisoned, till Pericles managed to rescue him with great difficulty, while Socrates, although the had nothing whatever to do with this kind of speculation, was nevertheless put to death for this connection with philosophy. It was not until later that the glorious fame of Plato shone forth, and served, not only through the example of his life, but also through his teaching that the forces of nature are

subject to a higher principle, to dispel the odium which had attached itself to such theories, thereby enabling them to circulate freely.

At any rate, Plato's friend Dion remained unperturbed, although an eclipse of the moon took place at the time when he was to embark at Zacynthus for his conspiracy against Dionysus, and the continued his voyage to Syracuse, landed there, and drove out the tyrant.

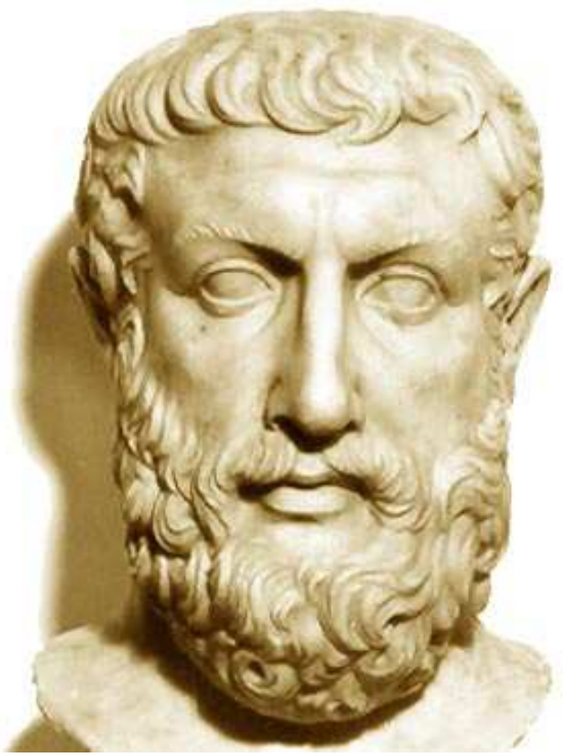
Parmenides: the father of logic

Parmenides of Elea and the excluded middle

Parmenides thought deeply about what we can know about the world. He came up with one incontrovertible truth: something either is, or it is not. There is no third option.

Example: the ball is red, or the ball is not red.

Does this sound obvious to you? It is one of the key Axioms of logic, on which all further science was based. It suggests that there is a truth out there to be discovered, if only one puts ones mind to it.



Parmenides
c. 540 – c. 450 BCE

Fringe benefits of science

Pericles had and unbounded admiration for Anaxagoras, and his mind became steeped in the so-called higher philosophy and abstract speculation. From it he derived not only a dignity of spirit and a nobility of utterance which was entirely free from the vulgar and unscrupulous buffooneries of mob-oratory, but also a composure of countenance that never dissolved into laughter, a serenity in his movements and in the graceful arrangement of his dress which nothing could disturb while he was speaking, a firm an evenly modulated voice, and other characteristics of the same kind which deeply impressed his audience.

Portents of the fall of Athens (Plurarch:Lysander 12)

There were reports that the brothers Castor and Pollux appeared as twin stars on either side of Lysander's ship and shone out over the rudders just as he started tout of the harbor against the enemy. Others say that this disaster was foreshadowed when the great stone fell, for there was a popular belief that a colossal stone had fallen from the sky at Aegospotami, and the people of the Chersonese revere it and point it out to this day. Anaxagoras is said to have predicted that if those bodies which are fixed in the vault of heaven should become loosened by some slip or convulsion of the whole system, one of them might be torn away and plunge to earth. He also asserted that none of the stars was now in its original position. According to his theory, they are heavenly bodies composed of stone, whose light is generated by the friction of the ether which whirls round them, and they are propelled in fixed orbits by the gyratory force which first set them in motion; it was this force which originally prevented them from falling o earth at the period when cold and heavy bodies became detached from universal matter.

However, there is a more convincing theory than this. Those who hold it reject the explanation that shooting stars are caused by a sudden rush or diffusion of burning ether, which is no sooner ignited than the lower air extinguishes it, or by the combustion caused by the lower air escaping to a higher altitude. They maintain that shooting stars are heavenly bodies, which because of some momentary suspension of the centripetal force which governs them are carried out of their orbit and fall, not into the inhabited regions of the earth, but in most cases outside it or into the surrounding ocean, and for this reason their impact passes unnoticed.

On the other hand Daimachus in his treatise *On Piety* supports Anaxagoras' theory. He states that a fiery body of enormous size was observed in the sky for seventy-five days continuously before the stone fell. It resembled a flaming cloud and it did not remain at rest, but was propelled along with intricate and irregular movements, so that the burning fragments, splintered off in its plunging and erratic course, were showered in all directions and flared up brilliantly in the sky, just as shooting stars do. But when it has fallen in that spot and the inhabitants

had recovered from their terror and astonishment and gathered round it, they could find not the least trace of the effects of fire: there was nothing but a stone, certainly of a large size, but by no means to be compared to the fiery mass they had observed in the heavens.

It is clear, of course, that Daimachus' account requires a good deal of indulgence from his reader. But if what he says is true, it entirely disposes of the theory that some rock, dislodged by wind and storm from a mountain-peak, was snatched up high into the air and carried along like a spinning-top, and that is plunged to earth at the place where its spinning motion first slacked and stopped. The alternative is that the phenomena which was witnessed for so many days in the havens really did consist of fire, and that when this was extinguished, a change in the atmosphere followed which produced disturbances and violent winds, and that these in turn tore the stone from its position. However, a full investigation of such problems belongs to another kind of writing.

Socrates (470/469 – 399 BC)

Our sources consist mainly of Plato and Xenophon (he never wrote anything).

He is known for his recognition that "he knows nothing", and reviled by some of his contemporaries for brilliantly showing that they know no more.

Politically he was supportive of the aristocratic cause which caused the anger of the democrats.

Executed in 399 BC, ostensibly for not recognizing the gods recognized by the state, introducing new deities, and corrupting the young.

Xenophon's memory of Socrates

Then again, Socrates was always in the public eye. Early in the morning he used to make his way to the covered walks and the recreation grounds, and when the agora became busy he was there in full view: and he always spent the rest of the day where he expected to find the most company. He talked most of the time and anyone who liked could listen. But nobody ever saw Socrates do, or heard him say, anything that was heretical or irreverent. He did not discourse about the nature of the physical universe, as most other philosophers did, inquiring into the constitution of the cosmos (as the sages call it) and the causes of the various celestial phenomena; on the contrary, he pointed out the foolishness of those who concerned themselves with such questions.

In the first place, he inquired whether they proceeded to these studies only when they thought they had sufficient knowledge of human problems, or whether they felt that they were right in disregarding human problems and inquiring into divine matters.

He expressed surprise that it was not obvious to them that human minds cannot discover these secrets, inasmuch as those who claim most confidently to pronounce upon them do not hold the same theories, but disagree with one another just like lunatics. He pointed out that some lunatics don't even fear what is fearful, and others are terrified of thins that aren't terrible; some don't scruple to say of do anything even in a crowd, and others feel that they can't even show themselves in public; some show no respect for temples and altars or anything else that is sacred, and others worship stones or odd pieces of wood and animals. In the same way, he said, some of those who ponder about the nature of the universe think that reality is one, and others think that it is infinitely many; some think that everything comes to be and passes away, and others that nothing can come to be or pass away.

He also raised this further question about them: whether, just as those who study human nature expect to achieve some result from their studies for the benefit of themselves or of some other selected person, so these studies f divine matters expect that, when they have

discovered the laws that govern the various phenomena, they will produce at will winds and rain and changes of season and any other such required effect [Empedocles did promise such things]; or whether they have no such expectation, but are content with the mere knowledge of how these various phenomena occur.

That is how he spoke about people who occupied themselves with these speculations. He himself always discussed human matters, trying to find out the nature of piety and impiety, honor and dishonor, right and wrong, sanity and lunacy, courage and cowardice, State and statesman, government and the capacity for government, and all other subjects the knowledge of which the through marked truly god men, while those who were ignorant of them might fairly be called slavish.*

*From Penguin Classics (1990): Xenophon, Conversations of Socrates, pp 70.

Aristotle (384 – 322 BC)

There are two distinct spheres: the earthly sphere dominated by generation and decay and the heavenly spheres which are eternal, perfect, and unchanging.

To understand the earthly world he developed a general theory of change which included the change of position, but also the change from sickness to health, or the change in color in a very abstract manner.

He held that the evolution of the heavenly spheres followed different laws and represented gods perfect design. (More about this in Chapter 5).

Observations on different forms of inquiry

Mathematics appears to develop only once since it consists only of logical inferences on basic axioms. Once Euclid had written his collection "The Elements" it remained unchanged and is still used in schools.

Physics is a subject that is confronted with observations from the real world. As such Physics is a changing subject, and Aristotle's Physics is now considered to be obsolete. (Largely due to Newton's work, that we discuss in a later lecture.)

Philosophy inquires into important human questions like: what should we do, what is right and wrong, what is our reason for being. Questions raised by ancient philosophers like Plato are continuing to be asked. While there has been much discussion and many new angles of view have been discussed, it appears that these old questions remain relevant even today.

Achievement of the Greeks

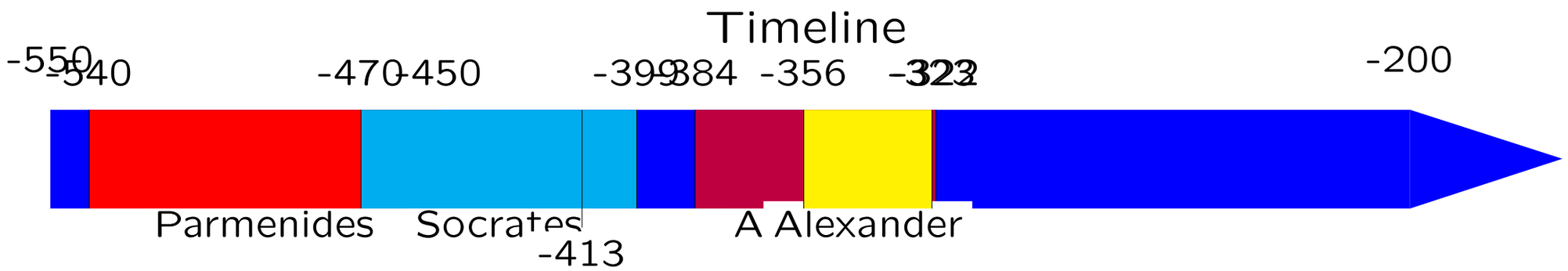
A key to perceiving the world around us is to first decide that there is something to perceive.

In Greece the environment appears to have been just right to generate men who would develop this fundamental paradigm: the world around us may be entirely (or at least largely) accessible to human understanding.

Little of what they found, would be thought of as science today, but the transition to a world where natural phenomena were not the sole prerogative of the gods but could be understood by human kind was a fundamental paradigm shift.

After the classical Greeks

Greece fell to Alexander of Macedonia ("the great")
Alexander's empire fell to three of this generals, including Ptolemy
Museum of Alexandria
Fall of Syracuse in the second Punic war: Archimedes
Stagnation of science in the Roman empire
The Islamic empire and its absorption of Greek science
The dark ages after the fall of the Roman empire.
End of the dark ages and the beginning of the Renaissance



Athen's general Nicia's retreat from Syracuse

Summary

The nature of what the world we are surrounded by is not obvious. The ancient Greeks dared imagine that there may be laws that govern nature that can be discovered by us. And they went ahead an speculated on what such laws might be.

In Mathematics (which was not closely related to Physics until much later) they found general laws that hold to this day, but speculations about the nature of our reality was widely divergent. The Greek approach was a hope that pure thought could discover such a description of nature. Since all such ideas have not only to be consistent in themselves, but are supposed to make predictive statements about our reality, they would have to undergo revisions to be adapted to the reality as we perceive it.

Most everyday phenomena turned out to be much too complicated to allow a good description by those methods. It took almost a millennium until quantitative methods were developed to compare predictions to observations.