Magnetism In The Roman Era

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Historical Background

The Roman period which we take roughly as the period from about 100B.C, to about 500 A.D. is a period of profound social change and upheaval. It begins with the civil wars of the Roman republic as it evolves into empire and ends with the economic and social disintegration of western Roman civilization. The period begins with political upheaval caused by the war between Sulla and Marius that ended with Sulla's appointment as dictator, marking the end of the Roman Republic. The decline in Greek power is sealed in 86B.C. by the sack of Athens. It is followed by a revival of Aristotelian and Greek knowledge, but this revival is primarily not directed to science or scientific method. It is primarily interested in logical method, ethics and moral reasoning, not scientific reasoning. The decline in science has traditionally been attributed to the rise of christianity, but this seems to have been a minor cause. By the time that Christian thought dominated the empire, scientific thought and method were already dead or nearly expired. The intellectual environment of the Roman empire was not conducive to scientific endeavor. The Romans were practical men, engineers not scientists.

Philosophic Influences of The Roman Period

The main philosophical school that influenced science during the early roman era was the Epicuran school. This school is significant because it is associated with the idea of a universal natural law. But the full scientific development did not mature until 1600 AD. The primary Roman philosopher who dealt with natural philosophy was Cicero, who transmitted many of the earlier Greek ideas into the Latin culture. But Cicero died with the republic and the advent of the empire. Curiously, the birth of the Roman empire, seems to mark the end of the scientific spirit in ancient times. The coincidence with the birth of Christ seems to be the reason for blaming the rise of Christian religion, but it seems more likely the true reasons are otherwise. When we examine the philosophy of the Romans, we see a marked lack of the philosophic enterprise that was the defining character of the Greek period.

The period ends with the upheaval of the division of the empire and the warfare of the emperor Justinian I. It coincides with the first scholastic Boethius who attempts to translate Aristotle from Greek into Latin. He manages only to translate a mere part of the huge body of Aristotelian literature. But, none it is concerned with Aristotle's scientific work. The result is that none of his scientific books survive into the early middle ages.

Roman Materialism

At the beginning of the Roman era, leaving the Greek age and passing to the Roman period, we encounter the Epicurean poet Titus Lucretius Carus (circa100-55BC). His long poem On The Nature Of The Universe gives a detailed explanation of the actions of the magnet upon iron rings. Lucretius is unique being the only example of what can be called a Roman scientist. But

Lucretius isn't really an original thinker in the mould of the Greeks. He borrows his ideas from the Greek atomists and elaborates upon them. Lucretius style tells us much about the Roman attitude towards scientific knowledge. He casts his book in the form of a poem. It is literary science, made palatable to the educated Roman class as elegant literature. This tells us much about the style of the period. Natural knowledge was a hard sell by itself, it was necessary to package it with style and literary elegance. For the Romans, we see that scientific philosophy, as philosophy itself, is an adornment for the educated, a mark of their cultured sophistication. It does not seem to have been pursued for the reasons of the Greeks.

Lucretuis was a disciple of Epicurus. His theory of magnetism, in almost all respects is borrowed from the ideas of Empedocles, Democritus and Diogenes. He adopts the materialistic viewpoint and presents essentially the same ideas as we discussed above, but in a more complete form.

Here the quotations derive from a modern prose translation which fails to convey the poetic aspect of Lucretius book length poem.[33] He begins with the following premisses regarding the emanations. Lucretius says echoing Empedocles:

> "In the first place, it must be a fact that all visible objects emit a perpetual stream and shower of particles that strike upon the eyes and provoke sight."

The emanations are described using the following analogy with water and its action:

> "So from every object flows a multiform stream of matter, rippling out in all directions. The stream must flow without rest or intermission,..."

The concept of the vacuum or void is introduced after the manner of Democritus but more convincingly:

> "Let me now re-emphasize, what is made crystal clear in my first book, the extreme looseness of the structure of all objects. ...it is especially necessary to establish that there is no perceptible object that does not consist of a mixtureof matter and vacuity."

This is backed up by the analogy of caves which exude moisture, and sweat from our bodies. His summary is simple and direct.

> "In short, nothing exists but amalgams of matter and space"

To explain the penetration into matter he says:

> "The innumerable interstices that occur in different objects must be possessed of mutually dissimilar natures, each having its own passage ways."

His preliminary arguments complete, he proceeds to the explanation of a chain of rings hanging from a magnet:

> "On this basis it will be easy to lay bare the whole cause of the attraction of iron. First, this stone must emit a dense stream or emanation of atoms, which dispels by a process of bombardment all the air that lies between the stone and the iron. When this space is emptied and

a large tract in the middle is left void, then atoms of the iron all tangled together immediately slide and tumble into the vacuum. The consequence is that the ring itself follows and so moves in with its whole mass."

The basic idea being that,

"..a cluster of particles from the iron cannot drop into the void without the whole ring following. This it does and continues to follow till it actually reaches the stone and clings to it by invisible ties."

Feeling that this is not sufficient he introduces a secondary explanation using the pressure of air as a contributory cause.

"The process is facilitated and movement helped on by a contributory cause: as soon as the air in front of the ring is rarified and the space fairly well emptied and evacuated, it thereupon happens that all the air situated at the back of the ring pushes and shoves it forward from behind. For objects are always being pelted by the surrounding air; but in this case it happens that the iron is pushed by the pelting because in one direction there is a vacuum ready to receive it. This air of which I am speaking creeps nimbly in through the many porosities in the iron and comes up against its tiny particles so as to push and drive it along as sails and ship are driven by the wind."

Here he seems to be introducing a second explanation and he proceeds to elaborate upon the air as a cause for the attractive force. Finally, to counter any objections regarding why the ring does not drop away after the ring has been attracted to the stone and then hangs there, he introduces a third mechanism to explain why the ring doesn't drop off after the void has been filled by its movement to the magnet.

"It is even possible for some things to be coupled together, as though interlinked by hooks and eyes. And such, it would rather seem, is the linkage between iron and magnet." If the reader is struck by the similarity to the explanations of the Greeks Empedocles, Diogenes, and Democritus, then he must conclude that Lucretius borrowed freely from them.

The explanation given by Lucretius has a strong aura of plausibility, but upon close examination we see that it has a number of serious flaws. To begin with, the premisses are incomplete. This may explain why the apparently different explanations are introduced. The explanation is divided into three parts: the creation of a vacuum, the circular thrust, and the movement into the void. The essential premiss that is missing is that matter moves in a direction so as to occupy a void. This is apparently a silent assumption, that underlies the explanation for magnetic attraction. It is based upon the theory of circular thrust, which itself is derived from the clepshydra experiment described by Empedocles. But, this explanation has flaws. The problem is twofold. First, to understand why only iron is attracted. If the emanations formed by the magnet create a void by forcing the air away, then the magnet should attract any kind of object towards it. The answer Lucretius gives is unclear and vague:

”The innumerable interstices that occur in different objects must be possessed of mutually dissimilar natures, each having its own system of passage ways...There is no need to be surprised that the effluence from this stone has no power to impart a similar motion to other substances besides iron. Some are held fast by their own weight, for instance gold. Others cannot be moved anywhere because their loose texture allows the effluence to pass through intact; a clear example of this class is wood. Iron, which by its nature lies midway between the two, needs only the addition of some particles of copper and then it yields to the current from the magnesian stone.”

Reading this, it becomes clear that the main flaw in this exposition is its attempt to reconcile the three fundamentally different kinds of explanation given by Empedocles, Diogenes and Democritus into a single coherent one. Lucretius has mixed up the different explanations with a confusing result. The second serious flaw is that there is no clear reason to explain why the air is effected by the effluences from the magnet. Its surely seems more reasonable to conclude that the effluences pass through the air without effect than through the iron.

To illustrate what I mean consider the following discussion which I omitted from the passages given above. Lucretius says:

“Again, all objects must contain air within their bodies, since all are of loose texture and all are encompassed and bounded by air. Accordingly the air that lies hidden in the core of the iron is perpetually surging to and fro in a restless motion. By this means no doubt it keeps on battering the ring and unsettling it from within. And by the same means the ring is, of course, kept moving in the direction in which it has once launched itself by its plunge into the vacuum.”

This passage seems to contradict the interpretation given above that the iron is pushed into the vacuum created between the magnet and the iron ring by the circular thrust. It seems to imply that the vacuum is created inside the iron by expelling the air that resides inside of it. This being Empedocles conception. It explains why only iron is attracted because the passages in the iron only allow the effluence from the magnet to penetrate inside of it.

Alfred Still in Soul Of Loadstone claims that the repulsive force of magnets was known to Lucretius and cites the following as his proof :

“It also happens at times that iron moves away from this stone; its tendency is to flee and to pursue by turns. I have even seen Samothracian rings of gilded iron jump up and iron filings grow restive inside copper cups when this magnet stone was put under them. So eager, it seemed, was the iron to run from the stone. The reason why the interposition of copper causes such a turmoil is doubtless this. After the effluence of the copper has first taken possession of the open passage ways in the iron and occupied them, along comes the effluence of the magnet and finds everything full in the iron and so has no way of passing through as before. It is therefore compelled to pelt and batter the texture of the iron with its stream. In this way it repels the iron from itself and through the copper it drives away what otherwise it normally attracts.”[9]

This is a rather surprising paragraph. It follows the passage in which he explains the motion of the iron as due to the motion of air within the iron “surging to and fro”. If we accept that the

repulsion of iron by the magnet was an established fact, it is evident why the explanation given by Lucretius appears to be confusing. He has to account for both attraction and repulsion by the means of effluence from the magnet. But it seems impossible that this theory could explain both attraction by movement into a void and repulsion by the same mechanism as well.

This paragraph presents a difficult question of discovery. Should we credit Lucretius with the discovery of magnet repulsion? No, because he didn't actually discover it, he reports it as a demonstration he has seen. It is an experiment, and it needs to be explained, as Lucretius attempts to do. But, again it is not a report of magnetic repulsion between like magnetic poles. It is a different phenomenon than this. It is the observation that iron can be both repelled or attracted towards a magnet. As such it seems to be a valid report of a real phenomenon of nature that needed to be explained by his theory of magnetic action.

Cicero's Roman Viewpoint on Greek Science

Lucretius died in 55B.C. during a period of great upheaval. Rome was in the midst of its great civil wars. Julius Caesar was consul and engaged in the Gallic wars. Although the period during which Lucretius book was written was one of warfare, it was also a period of the flowering of Roman literature and culture. The work of bringing Lurcetius unfinished book to publication was undertaken by the famous Cicero. Cicero completed Lucretius' book, but he had no love for Epicurianism. He gives us a glimpse of a Roman view of Greek scientific philosophy as follows:

"...as for natural philosophy, if I accepted the system of Epicurus, that is of Democritus, I could write about it as lucidly as Amafinius; for when once you have abolished causation, in the sense of efficient causes, what is there remarkable in talking about the accidental collision of minute bodies - that is his name for atoms? The natural science of my school you know; being a system that combines the efficient force and the matter which is fashioned and shaped by the efficient force, it must also bring in geometry; but what terminology, pray will anybody have to use in explaining geometry, or whom will he be able to bring to understand it?"

Having disposed of the Epicuran system, Cicero continues on to expound natural philosophy of the Platonic and Aristotelian tradition as he saw it:

"The subject of nature...they dealt with by the method of dividing nature into two principles, the one the active and the other the passive, on which the active principle operated and out of which an entity was created. The active principle they deemed to constitute force, the one acted on, a sort of "material": yet they held that each of the two was present in the combination of both, for matter could not have formed a concrete whole by itself with no force to hold it together, nor yet force without some matter (for nothing exists that is not necessarily somewhere). But when they got to the product of both force and matter, they called this 'body', and, if I may use the term, 'quality'..."

Here Cicero has defined the idea of a quality to mean the combination of the active and passive principles.

Cicero continues, discussing the nature of quality and clarifying the idea of element to mean the first principles of things, and not the modern idea of a fundamental material constituent:

"Well then, those qualities are of two sorts, primary and derivative. Things of primary quality are homogenous and simple; those derived from them are varied and 'multiform'. Accordingly air...and fire and water and earth are primary; while their derivatives are the species of living creatures and of things that grow out of the earth. Therefore those things are termed first principles and (to translate form the Greek) elements; and among them air and fire have motive and efficient force, and the remaining divisions, I mean water and earth, receptive and 'passive' capacity... But they hold that underlying all things is a substance called matter, entirely formless and devoid of all quality... and that out of it all things have been formed and produced..."

Later Cicero makes clear what the nature of this force is. He says:

"...this force they say is the soul of the world, and is also perfect intelligence and wisdom, which they entitle God, and is a sort of providence..."

From this short excerpt of Cicero, we see that he has summarized the entire thesis of the Greek viewpoint in just a few words. It is apparent that it is essentially the viewpoint of Thales informed by nearly 600 years of philosophical discussion. Later we will see how the ideas clarified by Cicero evolve into a theory of magnetism that is remarkably similar to our modern field theory.

Pliny's Natural History-A New Scientific Style

During the 1st century AD Pliny the Elder, who was killed in 79 AD during the eruption of Mount Vesuvius, wrote an influential book, Natural History, that is a valuable record of Roman scientific knowledge. We have already seen what Pliny has to report upon the nature of lodestone in the discussion of the Temple of Arsinoe. This compendium was one of the few ancient books that survived into the dark ages and conveyed Roman science into the middle ages. In his book Natural History, Pliny The Elder (Gaius Plinius Secundus) gives a long and confusing discussion of the mineral magnetite. The description mixes together the property of attraction for iron with medicinal and magical properties of minerals that do not exhibit attraction for iron.

> "Passing from the subject of marbles to other stones with striking properties, who would hesitate to deal first with the magnet? For what phenomenon is more astonishing? Where has nature shown greater audacity? We have already related how she gave rocks a tongue with which to answer man, more, to break in upon his speech. What is harder to move than the frozen stillness of stone? Lo, she has given it hands and feelings. What is more refectory than hard iron? Lo, she has given it feet and character. For iron, the tamer of all substances, is drawn by the magnet, follows some intangible attraction and, as it comes nearer, leaps to meet the magnet, is held, and clings fast in its embrace. So the magnet is given another name, sideritis, while some call it Heraclion. Nicander is our authority for believing that it was called magnes from the man who first found it on mount Ida (for they may be found everywhere, including Spain), and he is said to have discovered it

when the nails in his shoes and the ferrule of his staff adhered to it, as he was pasturing his herds."

"Sotacus classifies magnets into five varieties: the first found in Aethiopia, the second from the Magnesia which has a common boundary with Macedonia and lies on one's right hand as one makes for Iolcus from Euboea, the third found at Hyettus in Boeotia, the fourth from the neighborhood of Alexandria in the Troad, and the fifth from the Magnesia which is in Asia."

"The first point of distinction is whether the stone is male or female, the second depends on its color. Magnets found in the magnesia near Macedonia are a reddish black color, while Boeotian magnets are more red than black. The magnets found in the Troad are black and of the female sex, and are therefore without magnetic power, but the worst of all come from magnesia in Asia. These are white, with a resemblance to pumice, and have no attraction whatever for iron. It is an ascertained fact that, the more blue there is in the color of a magnet, the better it is likely to be. Those from Aethiopia bear off the palm, and sell for their weight in silver. They are found in Zmiris, for so they call the sand covered region of Aethiopia. In the same district is found the haematites magnet which is the color of blood and which gives, when powered, a material of a saffron-red hue. Haematites has not the same power of attracting iron as the magnet. It is proof of the Aethiopian origin of a magnet if it attracts other magnets. All these varieties are used, each in its due proportion, in salves for the eyes, and are particularly effective in arresting ophthalmic discharges. A magnet which has been ignited and powered is used for healing burns."

"In Aethiopia also, and not far from the previous locality, is another mountain which bears the stone *theamedes*, which drives away and repels every kind of iron. We have had occasion to mention these characteristics of attraction and repulsion on several occasions."

During the course of this discussion, Pliny briefly explains the cause of magnetic attraction as follows:

"Iron is attracted to the magnet: the substance that overcomes all else rushes into a kind of vacuum and, as it approaches the magnet, leaps toward it and is held fast and embraced by it."

From this we see that Pliny's Rome was not interested in a theory of magnetic action, the explanation given completely lacks important details, but in the descriptions of its amazing properties. The name magnet is therefore applied to any stone which has magical or healing properties.

It is important to notice that Pliny gives the theory that the attraction is caused by motion towards a vacuum. Hence, he has simplified Lucretius by taking the vacuum as the efficient cause of the attraction. This becomes the accepted interpretation during the Roman era as we will see later.

Pliny's book is the earliest example of a new style or scientific fashion. His emphasis is not on the theory or the explanation, but on a description of nature that is at once informative and entertaining. It is not characterized by objective accuracy, but is concerned with collection of facts that are amusing, informative, unusual and obscure - but above all interesting. There is no attempt to ascertain whether an astonishing new report is really true or accurate, the book is more like a newspaper than a scientific book. Pliny collects informative tales, obscure events, and unusual occurrences. He does not attempt to explain nature as the Greeks, but instead presents us with an entertaining collection of facts. Some are true, others merely superstitious tales. But it serves as a valuable compendium of historical facts from the Roman period useful for the modern historian.

One aspect of Pliny that presents a conundrum for the historian is the separation of fact and fiction. A very interesting example of this is the following description of Local Marvels:

"Near the river Indus there are two mountains: the nature of one is to attach itself to iron, while the other rejects it. Thus if a man has nails in his shoes, on one of the mountains at each step he is unable to tear his foot away from the ground, and on the other he cannot put his foot down."

We know that this story is pure fantasy, yet a doubt lingers over the idea that there is a mountain that repels iron nails. The report is certainly interesting because it asserts that a property of magnetism is that it both attracts and repels iron. What are we to make of this story? Is this a second record of the repulsive effect of magnetism? Perhaps it is pure fantasy, but on the other hand, what makes the story believable is the small germ of truth within it. The well known and verified attraction of the magnet for iron. Did the story arise because the repulsive effect of magnetism was also known but kept a secret for the use of the magicians and purveyors of the miraculous? We can't give a definitive answer, but the possibility is tantalizing that the repulsive effect of magnetism was known in Pliny's time but that definitive reports of it have not survived.

Traditionally, historians of science have treated reports in Pliny with caution and skepticism. An example is Pliny's report that the greek astronomer Hipparcus "...discovered a nova that came into existence during his lifetime." This statement contradicts the accepted historical belief that nova's were unknown in western europe prior to Tyco Brahe's discovery of a supernova in 1572. George Sarton, the founder of modern history of science, says that Pliny's statement is naive, but he does not reject it entirely, nor does he embrace it. On the other hand, another recognized authority, A. Pannekoek rejects it entirely in his definitive A History of Astronomy. He says "This short sentence does not allow us to decide..." Hence the conundrum of Pliny's Natural History leaves us with a dilemma. Can he be regarded as a reliable witness or not? There is no definitive answer. We can say, however, that Pliny's version of science can not be regarded as certain truth, he is two unreliable for that, but the irony is that his book was a recognized authority during the middle ages. The style was imitated and his reports propagated from one authority to another, all the while the learned scholars of western europe were thinking that they were engaged in science, but few of us living in the modern age would agree with that opinion.

Pliny laments that the pursuit of scientific knowledge had declined during the era of the empire. He tells us that,

"...nowadays, in this happy time of peace under an emperor, who takes such pleasure in promoting literature and science, absolutely nothing is being added to the sum of knowledge as a result of original research; indeed not even the discoveries made by people long ago are thoroughly assimilated." He attributes this decline to the fact that "Men's moral fiber has diminished with time, but not their revenues...their minds so blindly obsessed with greed, do not perceive that profit can be more surely made as a result of knowledge."

Pliny's trenchant comment still rings true today, but his point goes deeper than this. The assimilation of the advances in Greek knowledge had not proceeded rapidly. The Roman era probably should be conceived as period of consolidation of the new ideas. They were introduced into a world which lacked effective means to disseminate the scientific methods and discoveries. Education was restricted to the highest classes and its methods were crude and unsystematic in general. The diverse collection of schools taught different philosophies and advocated different methods of education. Knowledge was not uniformly systematic. True knowledge was elusive because one school denied the truths taught by another. Philosophy and scientific truth was fragmented, confused, and controversial. Add to this the problem that scientific knowledge was in Greek and the rulers of the world spoke Latin, it is easy to see why science declined under the aegis of the empire.

Influential Greeks of The First and Second Century

The period of the first century was one of dramatic change for the Roman empire. Christian thought was sweeping the empire. Its message, primarily a religious one, had far reaching implications for philosophy and scientific thought. Greek philosophy flourished in isolation, but the golden age of Plato and Aristotle was over. The vital impetus and the unparalleled growth of creative thinking was over. By the second century Greek science was waning, but creative minds were still active. Here we are concerned with Greek and Roman authors who were particularly influential during the middle ages after the fall of the Empire. They are Plutarch, Ptolemy, and Galen.

Plutarch, born in Boetia around 47 A.D. was a writer, who flourished during the reigns of Trajan and Hadrian. He studied rhetoric, philosophy, science and mathematics in Athens and Rome. He is best known as an historian for his Lives of Illustrious Men.[2] In these quotations from his Platonic Questions[3] Plutarch discusses the attraction of loadstone and amber.

> "[The loadstone] emits strong exhalations, by which the adjoining air being impelled forceth that which is before it; and this [air] , being carried round in the circle and returning into the vacated place, forcibly draws the iron in the same direction."[34]

This passage shows that Plutarch combined the emmanation theory with the concept of circular thrust found in Plato's Timaeous. Plutarch extends this conception to form a theory of the electrical attraction of amber:

”In amber there is a flammeous and spiritous nature, and this by rubbing on the surface is emitted by recluse passages, and does the same that the loadstone does.”[34]
These explanations are basically the same as given in Plato’s Timaeus.[4] The theory of circular thrust is invoked to account for both electric and magnetic attraction. For electrical attraction, Plutarch provides some additional information. He attributes the action of amber to a “flammeous and spirituous nature”, which is activated by rubbing the surface. This is released from the pores or as he says, “recluse passages.” This apparently explains the difference between electricity and magnetism. Amber required that it be stimulated by rubbing in order to release the exhalations from its pores. The attraction is then caused by the action of the circular thrust[3].

Another important aspect of Plutarch’s theory is his distinction between electricity and magnetism. He does not say that they are similar, but provides a description which emphasizes their differences. The emanations from amber consist of a “flammeous and subtle spirit”, while the magnet has “strong exhalations.” Plutarch is clearly making a distinction and implies very strongly that the emanations which operate by pushing the air by the circular thrust, are fundamentally different for electricity and magnetism.

Plutarch does not give details regarding the nature of the “strong exhalations” emitted by the loadstone and the “flammeous and spirituous” emanations of the amber. These could be either immaterial or corpuscular. However, he seems to have been very familiar with the atoms of Democritus and we may suppose that this is what he intends. Notice that this explanation is an occult or hidden cause. Plutarch uses it to justify both the occult virtue of the magnet and the cause of dreams. This becomes a major theme in the middle ages, where the use of occult virtues are capable of explaining many fantastic phenomena.[5]

Plutarch believed in divination by dreams and omens, and attempted to give a dignified explanation of it. He professed that the human soul had a natural faculty for divination, which he justified using Democritus theory that dreams were caused by images of souls from other bodies. In Plutarch we see an interesting consequence of the materialist idea that the soul is composed of atoms. Plutarch explains that in dreams, the souls of others can enter our dreams, by entering the body of the sleeper through the open pores in our bodies and thereby effect the mind. This is a rather fantastic consequence of the atomic theory. These emanations were also responsible for the fascination of love and other emotions such as hurtful looks. Here we see that Plutarch, who believes in occult virtues, divination and other magic arts, can justify them rationally by the action of the atoms of Democritus.[5] Plutarch presents us with a difficulty. Should his views be seen as a materialist or immaterialist. The answer is not clear because we are not sure just what he means by his strong exhalations and flammeous spirit. He seems to combine ideas from both of these viewpoints.

The famous Alexandrian Greek astronomer Ptolemy is known for his work in astronomy, geography, and optics. His most famous work is the Almagest which presents his theory of the solar system and planetary movements. This sun centered system sanctioned by the Church, was the orthodox interpretation throughout the middle ages, until challenged by Copernicus and later overturned by Galileo in the seventeenth century. It is not as well known that Ptolemy wrote an important book on Greek astrology the Tetralibos (Four Books) in 140AD. To fully understand this, we need to consider that modern astronomy evolves from astrology which is the older art.

Astrology is divided in two parts. The first part called natural astrology is our modern science of astronomy. It consisted of observing and recording the movements of the planets and locations of the stars. The second division is known as judicial astrology. This is our modern astrology, which casts horoscopes and studies divine guidance in human affairs. This type of astrology was very influential during the middle ages. Its importance to magnetism is that the directive property of the compass was interpreted as caused or controlled by the astrological influence of the stars. Here we see that magnetic phenomena seemed to support the idea that the stars actually influence human destiny. In Ptolemy's time astrology was a dignified art, and its influence during the middle ages was significant.[6,7]

The most important figure of the 2nd century after Christ is the Greek scientist known simply as Galen. He is one of the greatest scientific minds of his age. His influence in medicine during the middle ages was tremendous. His influence during the Christian era is probably due to two reasons. His opposition to the materialist philosophy of Epicurus and his philosophy that all is determined by God.

Galen was born in 129 A.D. in Pergamum in Asia Minor. His fame derives primarily from his books on medicine. Galen lived from 129 to 200 A.D. and practiced medicine in Rome. Galen was probably the most prolific writer of this period; having written more treatises than any other Greek. His output being twenty volumes. He is most famous for his medical texts. Some sources tell us that Galen knew of cures using the electric shock of the torpedo. This being a common Roman practice used to cure headaches, gout, and other ailments. [8,9]

Galen is important because of his severe criticism of the Epicurean theory of the magnet which was mentioned in the chapter on the early immaterialist theory of the magnet. Galen was opposed to the doctrines of the empirics and the Epicureans. We see this in his opposition to the Epicurean theory of the magnet. Galen believed that the attractive power of the magnet indicated that nature in us is divine. This is an application of his philosophical belief that all is determined by God. For Galen, the structure of the body is a reflection of the divine plan of God. He opposed the mechanistic theory of the atoms, and advocated that the human body is pervaded by spirits of different kinds. While our interest is in magnetism, Galen's significance is because of his influence during the middle ages.[9]

Galen objected to the materialist conception of magnetism as experessed by Epicurious and elaborated by Leucrutius. Galen writes in <u>On the Natural Faculties</u>:

"Now Epicurus, despite the fact that he employs in his Physics elements similar to those of Asclepiades, yet allows that iron is attracted by the lodestone, and chaff by amber. He even tries to give the cause of the phenomenon. His view is that the atoms which flow from the stone are related in shape to those flowing from the iron, and so they become easily interlocked with one another; thus it is that after colliding with each of the two compact masses (the stone and the iron) they then rebound into the middle and so become entangled with each other, and draw the iron after them... I fail to understand how anybody could believe this. Even if we admit this, the same principle will not explain the fact that, when the iron has another piece brought in contact with it, this becomes attached to it... As a matter of fact, I have seen five writing-sylets of iron

attached to one another in a line, only the first one being in contact with the lodestone, and the power being transmitted through it to the others."[32]

Here we see the conflicting viewpoints expressed clearly. The materialistic explanation fails to adequately account for the phenomenon of induction, which communicates the power of attraction from its source in the loadstone to iron objects suspended from it so that they hang in a chain. The materialistic theory fails, having met a crucial experiment it can not adequately account for. The explanation given by Plato in Ion is inadequate because in the opinion of the materialists, no material cause is specified so it must fail because only a material cause is capable of effecting physical actions. By modern criteria both fail, because they do not address how the attractive force is communicated from the loadstone to the suspended iron.

Galen is clearly an exponent of the immaterialist interpretation of magnetic action. He stresses that the communication of the magnetic action from writing stylet to stylet can not be explained by the Epicurean theory. His objection is based on his primary belief that

"The attractive power of the magnet...suggests to him that nature in us is divine, as Homer says, and leads like to like and thus shows its divine powers."

Galen's theistic attitude of mind appealed to Christians and explains the popularity of his writings throughout the Christian era.

Alexander of Aphrodisias Aristotelian Magnetic Theory

The closest thing we have to an Aristotelian discussion of magnetism is the analysis developed by Alexander of Aphrodisias at the beginning of the third century of the Christian era. The formal writings of Aristotle contain no discussion of magnetism, a significant omission, even though this subject was addressed by Plato in two different dialogues. In the previous chapter, this problem was discussed in relation to Aristotle's analysis of the soul. Aristotle concluded that the idea that the soul is the source or cause of self motion was impossible. This had the result that explanations of the magnet no longer commanded interest because of a desire to understand the soul. But it now became a problem to explain self motion within the Aristotelian framework. Alexander was the first to attempt to do this. But, the problem was a difficult one. The Aristotelian theory of motion as presented in Aristotle's Physics required a material contact to impart motion to the iron moved by the magnet. The lack of this material contact was a serious difficulty.

We know that Alexander was appointed a public teacher of Aristotelian philosophy between 198 and 209 A.D. It is believed that he was the leader of an Aristotelian school, probably in Athens. His writings have come down to us as commentaries, probably used as lecture notes, on Aristotle's works. We find his discussion concerning the magnet in his book Quaestions, referred to as quaestio 2.23 (the second part item 23).

The commentary by Alexander is the first scientific analysis of magnetism. Although it is not scientific in the modern sense, it follows the scientific method of Aristotle. This involves the careful analysis of the previous theories of magnetism in light of the method of logical analysis

developed by Aristotle. It begins by an evaluation of the theories advanced by the materialists Empedocles, Diogenes, and Democritus. As we would expect, Alexander rejects these ideas. But, he does not give an alternative interpretation that is clear and understandable. This seems to have been a characteristic of the Aristotelian method. When we read Aristotle we find a detailed critique of opposing viewpoints but we usually do not find a positive theory advanced in opposition. Hence we see that the Aristotelian method is better at examining the opinions advanced as positive truth, than advancing true opinions of its own. Aristotelian science is better adapted to a critical evaluation of scientific truth than establishing its own truth. We will see that this changes in the middle ages where the Aristotelian method becomes a standard authority for truth in scientific matters, and loses its view of scientific truth as "true for the most part".

It is probable that the purpose of this commentary is to refute the views of the Stoic school, which as we have seen, promoted the materialist theory of Epicurus and Lucretious. When we carefully study Aristotle, we see that his primary effort is to refute the views of other philosophers. He does this in considerable detail. He examines all the proposed theories of his predecessors and gives detailed arguments refuting them and pointing to the deficiencies of their theories. He then presents his theory and gives reasons why this is a satisfactory explanation. This is the method used by Alexander in his commentary on the magnet in quaestio 2.23. The approach is so familiar to us today, because it is common practice, that we fail to appreciate that it is a significant innovation that advanced the technique of philosophical argument.

Alexander is clearly advocating the immaterialist viewpoint. Alexander is our primary source for the early Greek materialistic theories of magnetism. We saw in the previous chapter that Aristotle refuted their views regarding soul as a motive force. It appears that Alexander is attempting to fix the omission regarding the magnet which Aristotle does not discuss. Clearly Aristotle's argument is incomplete for this reason. While he refutes the views of the atomists and criticizes Thales, he does not apply this argument to the magnet. This is a serious flaw because the magnet is the main phenomena that demands an explanation, but none is forthcoming in the corpus of Aristotle's works. Perhaps it has been lost, but we can not know this for sure. It is absent. Alexander's goal is to repair this omission.

Alexander argues that the attraction of the magnet for iron is not to be attributed to the way in which the womb attracts the seed, and the veins nourishment, by drawing in intervening air or moisture. But rather, he conceives the attraction as similar to the way in which an object of desire attracts a living creature, because the magnet possesses some feature or property in which the iron is deficient. A later philosopher, Simplicius, gives a more modern interpretation. He describes Alexander's theory as "asserting that the magnet attracts things by an incorporeal force". Here the operative concept is one of sympathy. But, we must remember that this idea is rather crude and imprecise. The ability of language to convey it is limited. Our modern language is more precise. We have a word to describe what Alexander means. Our modern concept which describes this state or process of attraction is magnetic induction. In this way, our idea of the magnetic field corresponds crudely to Alexander's incorporeal sympathetic force of attraction.

The discussion given here may be misleading in that it gives a large place to the discussion of the Aristotelian viewpoint. But this is because we seek the continuity of ideas about magnetism, and not the relative importance of these different ideas to the contemporary philosophers. It is

probable that the Aristotelian school represented by Alexander was a small one with little philosophical influence during its own time. The main objective has been to show that the Aristotelian school of thought, with its emphasis upon the incorporeal nature of the attraction as demonstrated by experiment, corresponds with the modern idea of the magnetic field. The main principle being that the attractive force is not due to a material cause.

Summary and Conclusion

When we look at the Roman period of scientific development, we see that it is devoid of any real philosophic innovation that can be considered scientific. On the other hand, there is a marked rise in the spread of culture during this period and a marked rise in living standards. To see this, one simply needs to compare pre and post Roman Britain with Roman Britain. The Roman period is marked by a highly developed economic system and infrastructure. The Roman roads and communities are marvels. They had bath houses and central heating. But, these are engineering and economic achievements. The Roman civilization flourished without the pursuit of philosophic science. This is not to say that Greek science did not continue, it did, but it was not close to the heart of the Roman culture, which was materialistic and practical. We should look to this as the reason for the decline of science during this period. In De aquis urbis Romane, Sextus Julius Frontinus, a proud Roman who supervised the Roman water works, says enthusiastically regarding the Roman engineering achievement in providing the water supply for Rome: "With such an array of indispensable structures carrying so many waters compare, if you will, the idle Pyramids or the useless, though famous works of the Greeks".

The primary problem in magnetic theory during the Roman period was the problem of immaterial force. The Greeks believed that an immaterial substance was incapable of acting upon a material substance to give it motion. This intellectual stumbling block remained unresolved throughout the period. But, it was clear that the atomic theory was unacceptable for the reason that it could not explain the phenomena of induction and attraction.

It is also clear that we can attribute the rejection of the materialistic theory of magnetism to the rise of Christian thought. This seems to have been a reaction to the predominant materialism of the Romans. The collapse of the materialist Roman civilization, left a vacuum that was filled by the Christian church as the only remnant of the Roman world. But, this was a spiritual culture that existed side by side with the pagan cultures of western europe. The result was not conductive to the development of philosophical science based on a materialistic viewpoint.

To end this section consider the following beautiful poetic sentiment written by Claudius Claudianus, a Latin poet of the late fourth and early fith century A.D.:

"There is a stone, colorless and without brilliance,...but it is preferred to all the most precious products of the orient by those who know its virtues and its wonders. Iron gives it life; iron recognizes and nourishes it; when the iron is withdrawn, it experiences the torments of hunger and thirst; it dies...Iron and the loadstone are drawn together and united. What can be this subtile flame which entering these two metals, can give rise to this sympathy? What is the unknown charm which can unite them with a common will and a single desire?"

The answer is the mystery of the loadstone. A mystery not solved but clearly defined by the wonderings of this poet. A mystery which endures even today. This poet expresses the magnetic theory current at the close of the Roman period. It is an idea that reminds us of Alexander of Aphrodisias' view of magnetic attraction.

To conclude this discussion, we discovered that the basic concepts for the materialistic idea, based on emanations, were established mainly by the Greeks. These continued basically the same up to the scientific age. Often the details may change, the mechanisms vary, but in all respects the main ideas remain unchanged. These are the emanation of a material substance, and a mechanism by which the emanations pull the iron, or in the case of amber, the light chaff towards the source of the emanations.

To understand his viewpoint, lets return to the theory proposed by Diogenes of Apollonia. Diogenes claims that the attraction of the magnet occurs when the iron draws into it the effluences of the magnet.

Next Chapter **Exit**