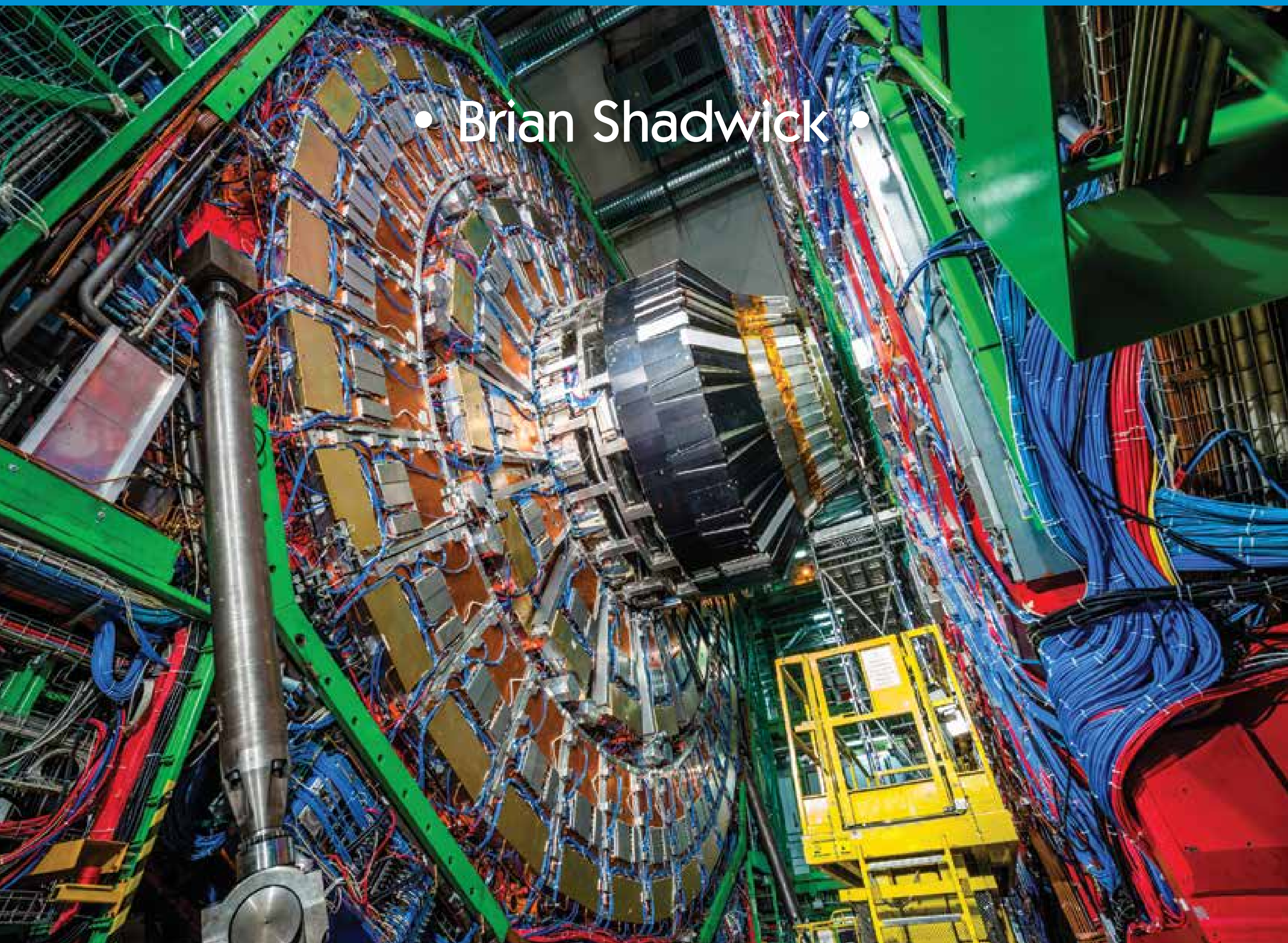
Surfing

NATIONAL PHYSICS

Unit 4 Revolutions in Modern Physics

• Brian Shadwick •



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Introduction

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

Words To Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

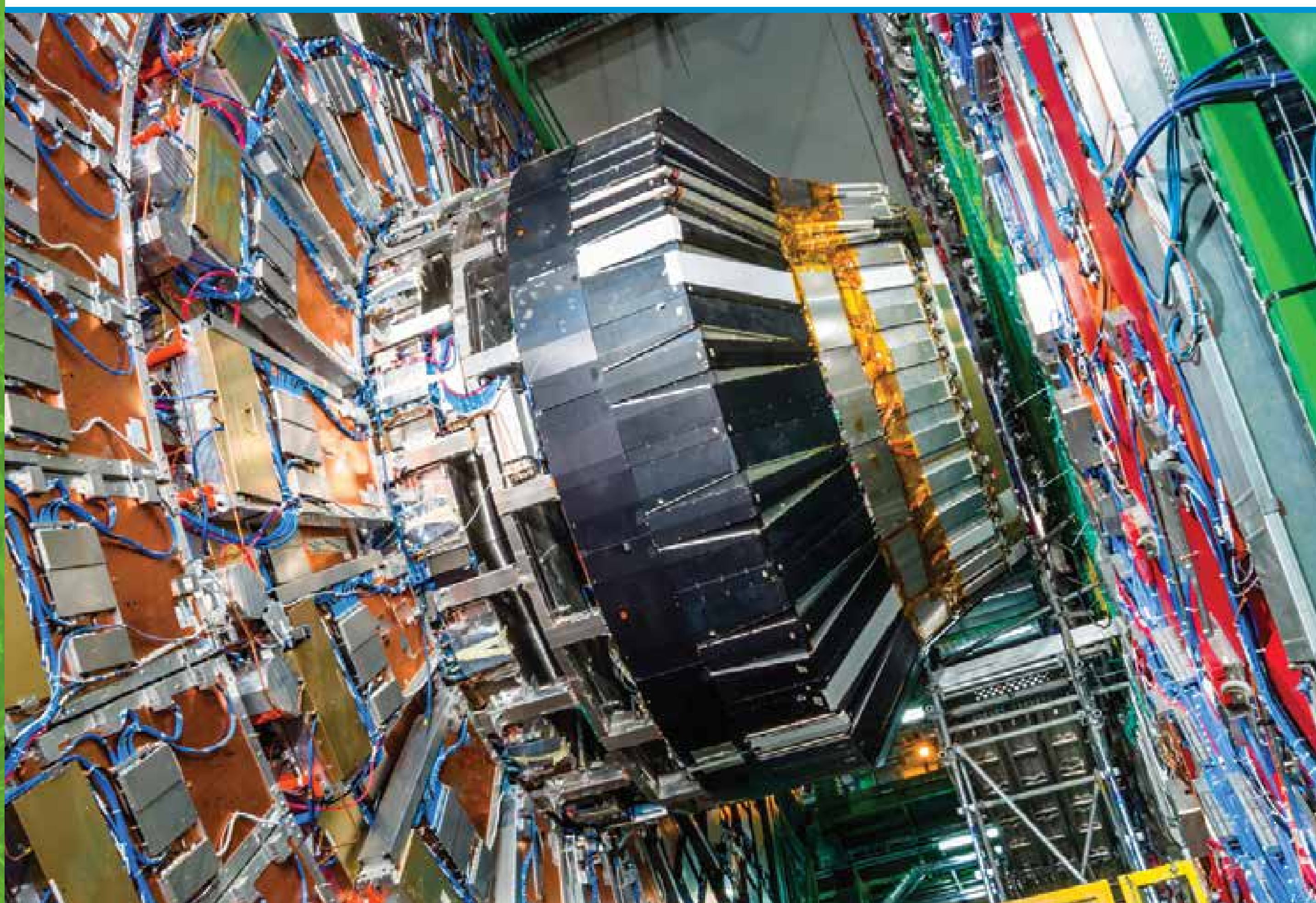
state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

Special Relativity



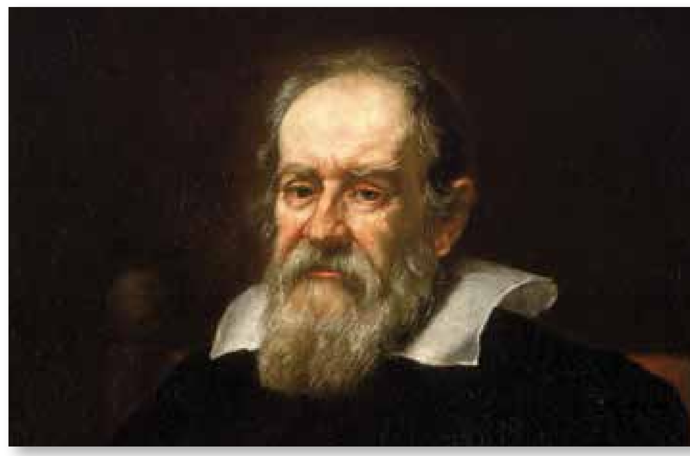
1 Relativity in the 1600s

Note: Our limited understanding of the mathematics involved forces the following historical account of relativity to be very generalised and to focus on major developments rather than details.

Special relativity arose from work scientists were doing to understand the nature of light. A major change in the late 1800s provided a new strategy for discovery in physics. Mathematics had progressed to the stage where it was able to predict properties of matter and various aspects of the nature of the Universe.

When we study special relativity in schools, we usually attribute it all to Albert Einstein. Not so. Many scientists starting from Galileo and Isaac Newton all contributed to our understanding of the relativity of motion. Einstein was even not the first to develop the equations we use for time dilation and length contraction – these were developed by Hendrik Lorentz and Henri Poincaré. He was not even the first to suggest that time dilation and length contraction occurred. In fact, Einstein was not even the first to propose that the speed of light was constant – James Maxwell's mathematics predicted this in 1873.

Certainly, the 'revolution' of Einstein was built on the shoulders of a lot of others, and Einstein got far more credit for his role than those who did the initial work. At the same time, it must be noted that Einstein took basic concepts and put them on a theoretical framework which changed them from partial solutions to a dying theory of the aether to fundamental aspects of nature in their own right. Perhaps history has rewarded Einstein for this insight and boldness.



Galileo Galilei (1564-1642).

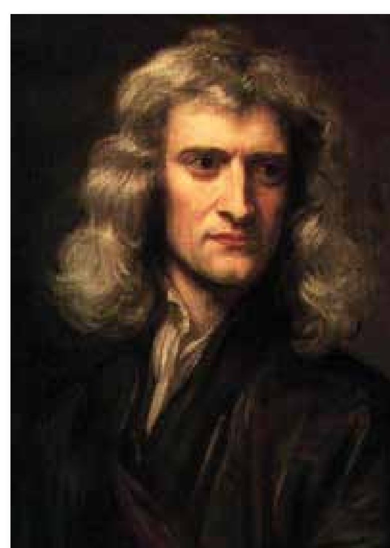
1632 Galileo Galilei

Galileo was perhaps the first scientist to make conclusions based on observations and experiments rather than from philosophical beliefs. Because of this he could be regarded as the 'father' of the scientific method.

He was the first scientist to propose a **principle of relativity**. He stated that constant linear motion only had meaning if it was measured relative to something else. So, two objects moving in the same direction at the same speed would actually be at rest relative to each other – their motion has no bearing on their relationship to each other.

Galileo, long before Einstein, proposed that there was no absolute reference frame – that is, a frame of reference which is absolutely stationary relative to everything else in the Universe.

Galileo developed a set of laws to describe motion along with the mathematics to describe them. Today we know this work as 'Galilean transformations'.



Isaac Newton (1642-1727).

1687 Sir Isaac Newton

Newton published his book *Philosophiae naturalis principia mathematica* (or just *Principia*) in which he described his ideas about light, motion and gravity – ideas which dominated scientific thinking for the next 300 years.

In contrast to Galileo, Newton inferred the existence of an 'absolute space' – an absolute reference frame – on which he based his theory. He derived a set of three equations to describe uniform motion.

In his **classical** physics, time was the same for everything, but light was composed of **particles**. All other known waves required a medium for their propagation, so light must also. This medium was called the 'luminiferous aether.'

One of its major problems was that the aether had conflicting properties. It needed to be extremely dense to account for the high speed of light, while at the same time had to be extremely insubstantial because we can't see it, or feel it or detect it and it doesn't slow down the Earth as it travels through it. The search for the aether, or proof of its existence occupied many scientists for many years.

2 The Aether Drag Theories

The aether and the motion of the Earth

An important part of the discussion about the aether was how the Earth moved relative to it. Did the Earth move freely through the aether? Was the asther dragged along with the Earth? Was it both within moving matter as well as being partially dragged by it (the **aether drag hypothesis**). If light travels through a glass slab does this mean that the glass is full of aether?

If it is completely dragged along with the Earth, then there will be no relative motion between the Earth and the aether. If it is only partially dragged along with a moving body there would be relative motion between the aether and the Earth and the magnitude of this relative velocity would depend on the speed of the Earth (or any other moving object). This would produce an 'aether wind', and this aether wind should be measurable by instruments at rest on the Earth's surface.

1804 Thomas Young

Young performed and analysed a number of experiments with light. He described the interference of light from reflection off narrow grooves etched into metal, from reflection off thin films of soap and oil, from the edges of barriers and after passing beams of light through single and double slits in barriers.

His analyses led him to propose, in opposition to the famous Newton, that light is composed of waves and propagates as a transverse wave motion.

1810 François Arago

Arago realised that differences in the refractive index of a substance predicted by the particle theory of light would provide a useful method for measuring the velocity of light. He attempted to measure the refraction of light particles by a glass prism at the front of a telescope.

He expected to discover a range of different angles of refraction due to differences in the relative velocities of various stars compared to the Earth at different stages in its rotation about the Sun. His results did not support his hypothesis.

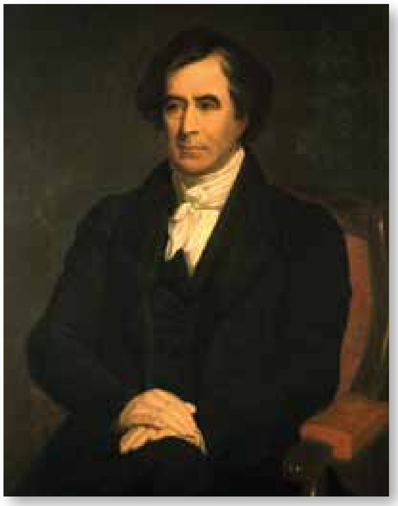
1818 Augustin-Jean Fresnel

Fresnel studied Arago's results using Young's wave theory of light. He realised that even if light were transmitted as waves rather than particles, then the refractive index of the glass-air interface should vary because of the movement of the glass through the aether.

To explain Arago's negative results, Fresnel proposed that the glass prism would carry some of the aether along with it. He realised that the velocity of propagation of waves depends on the density of the medium so he proposed that the velocity of light in the prism would need to be adjusted by an amount of 'drag' caused by the presence of the aether in the glass. He concluded that the aether is partially entrained by matter.

Fresnel's almost stationary theory seemed to be supported by the results of the 1851 Fizeau experiment.

Thomas Young (1773-1829).



François Arago (1786-1853).

Augustin-Jean Fresnel (1788-1827).

1845 George Stokes

Stokes proposed that the aether is completely entrained within or in the vicinity of matter. He argued that the aether is condensed and completely dragged within a medium and expands when it leaves the medium. This compression and expansion changes the speed of the aether, and therefore changes the speed of light which is carried by the aether within the matter.

George Gabriel Stokes (1819-1903).

1851 Hippolyte Fizeau

Armand Hippolyte Louis Fizeau (1819-1896).

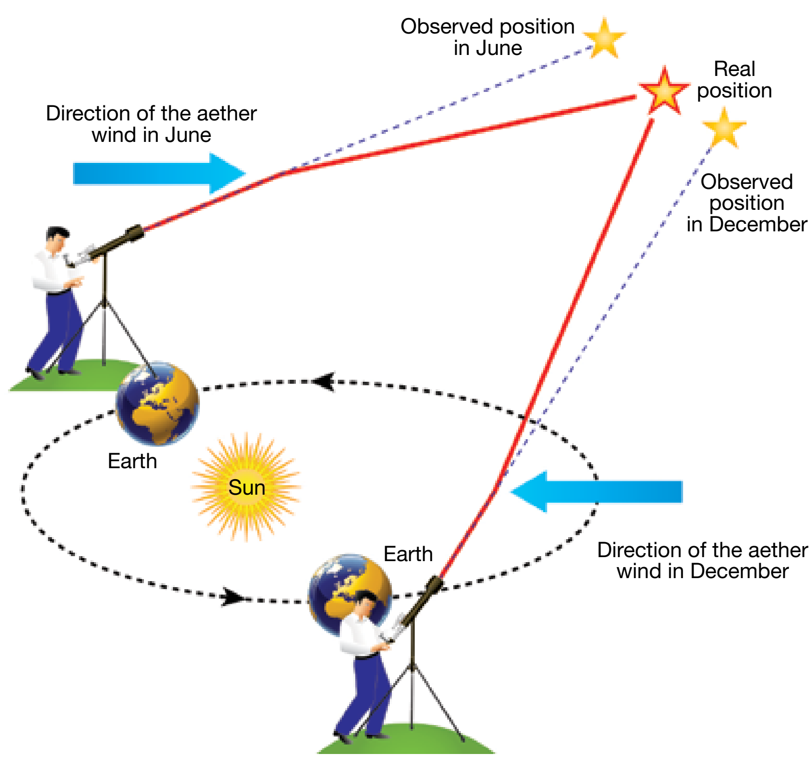
Fizeau conducted an experiment to measure the relative speeds of light in moving water. He used a special interferometer arrangement to measure the effect of movement of a medium upon the speed of light.

According to ideas at that time, light travelling through a moving medium would be dragged along by the medium, so he expected that the speed of light in the moving water would be a simple sum of its speed through the water plus the speed of the water.

Fizeau detected what he interpreted as a dragging effect, but its magnitude was far lower than expected. He interpreted his results as supporting the partial aether drag hypothesis of Fresnel.

QUESTIONS

1. (a) What was the aether?
   (b) Why was the existence of the aether hypothesised?
   (c) What evidence did early scientists have for the existence of an aether?
   (d) What is aether drag?
   (e) What were the two opposing aether drag theories?
2. (a) What is the aether wind?
   (b) What are the implications for an aether wind if the aether is totally dragged along with the Earth?
   (c) What are the implications for an aether wind if the aether is only partially dragged along with the Earth?
   (d) What are the implications for an aether wind if the aether is not dragged along with the Earth at all?
   (e) What was the importance of experiments done to detect the aether wind?



3. The diagram shows how the apparent position of a star changes when it is viewed from Earth six months apart. Scientists proposed that the movement of the Earth relative to the aether wind caused a dragging effect which caused this result.
   What is the real explanation for this?

3 Relativity 1870 to 1895

1873 James Clerk Maxwell

In the early 19th century, light, electricity and magnetism began to be understood as aspects of electric and magnetic fields.

Maxwell connected the known fact that changes in magnetic fields cause changes in electric fields and vice versa, and predicted that these electric and magnetic waves travelled as an electromagnetic radiation, not as a transverse matter wave.

He used this idea to develop a theory of electromagnetism by deriving a set of equations to explain electricity and magnetism. These are known as Maxwell's equations. He first proposed that light was an electromagnetic radiation in the same aether medium that was the cause of electric and magnetic phenomena.

The equations predicted the speed of these electromagnetic waves to be a constant 3×10^8 m s^{-1} which was known to be the speed of light – that is, it did not depend on the speed of the source of the light. His ideas were based mainly on the fact that the speed of light was so much greater than the speed of any other known waveform.

James Clerk Maxwell (1831-1879).

From this, Maxwell predicted that light was also electromagnetic in nature and was part of a much broader band of electromagnetic radiation. However, while Maxwell's theory was able to describe the motion of moving bodies mathematically, his ideas were not widely accepted because he was not able to provide an acceptable physical description of the aether. His theory later turned out to be compatible with special relativity, even though special relativity was not known at that time.

1881 JJ Thomson

While working on the nature of electrical discharges in vacuum tubes Thomson observed that charged bodies are harder to set in motion than uncharged bodies. He proposed that the mass of a moving object increases with speed. It was his idea that motion through electromagnetic fields would result in an interaction between the object and the field which would produce an increase in mass.

1881 Albert Abraham Michelson

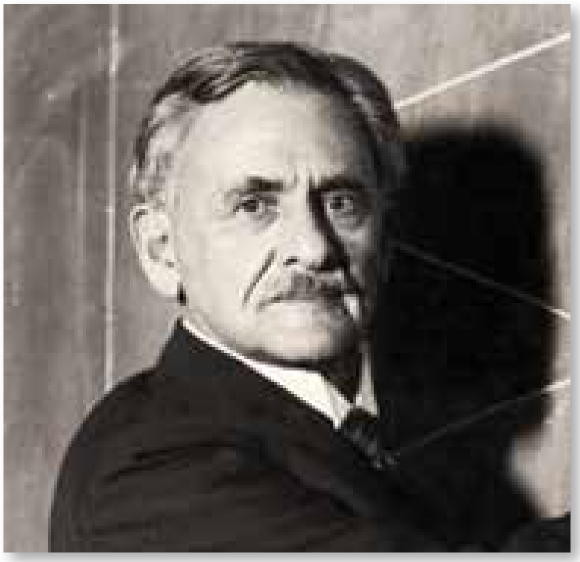
Michelson tried to measure the relative motion of the Earth to the aether, as predicted by Fresnel's partial aether drag theory. He could not determine any relative motion so he interpreted the result as a confirmation of the complete aether drag theory proposed by Stokes.

1886 Hendrik Lorentz

Lorentz demonstrated that Michelson's calculations were incorrect. Lorentz showed that Michelson had overestimated the accuracy of his measurements and proposed that this made Michelson's results inconclusive. Lorentz supported the partial drag theory of Fresnel's.

1886 Michelson-Morley

Michelson and Morley repeated the Fizeau experiment to confirm Fresnel's results. This changed Michelson's opinion and he now considered Fresnel's partial dragging theory of the aether was the correct one.



Albert Abraham Michelson (1852-1931).

1887 Michelson-Morley

To confirm Fresnel's partial drag theory, Michelson and Morley conducted experiments to prove the existence of the aether. Their null result in fact supported Stokes' complete drag theory.

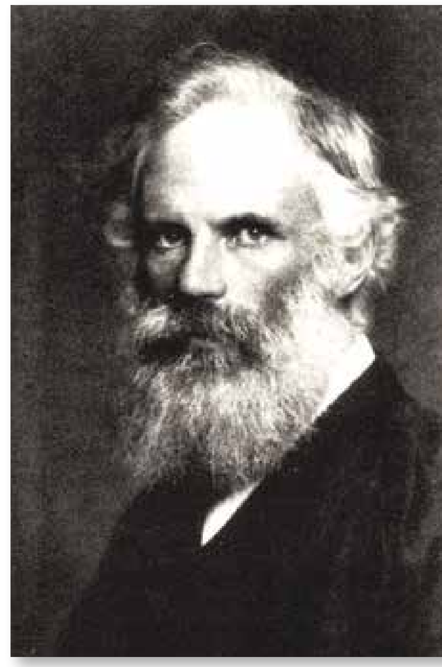
Physicists of the period were confronted with two seemingly contradictory experimental results – Michelson's 1886 experiment as an apparent confirmation of Fresnel's stationary aether theory, and the 1887 Michelson-Morley experiment as an apparent confirmation of Stokes' completely dragged aether.

1887 Heinrich Hertz

Hertz discovered what we now know as radio waves. These were the first electromagnetic waves to be discovered (apart from light) and this discovery provided support for Maxwell's theory.

1889 George FitzGerald

Fitzgerald published the first known paper about a relativistic effect, claiming that the Michelson-Morley experiment could be explained introducing a length contraction in the direction of the movement. He speculated that the intermolecular forces are possibly of electrical origin so that material bodies would contract in the line of motion.



George Fitzgerald (1851-1901).

1892 Lorentz

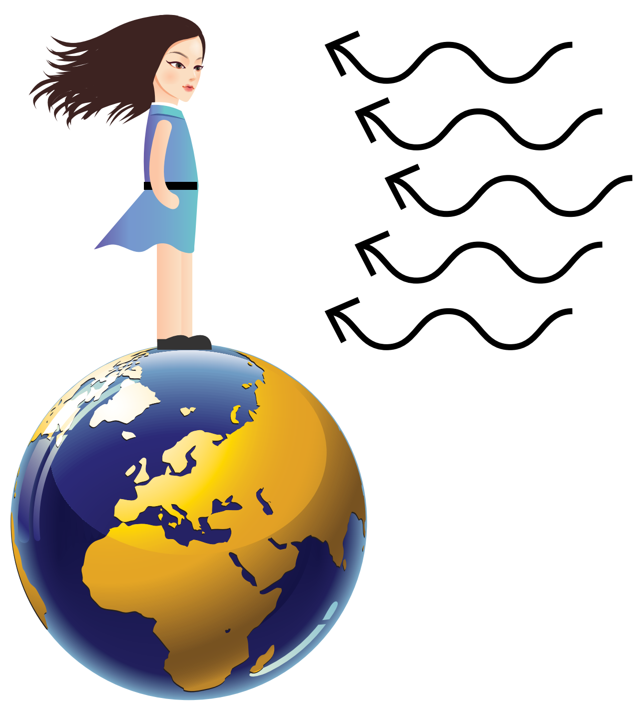
Lorentz proposed length contraction independently from Fitzgerald in order to explain the Michelson-Morley experiment. In this year Lorentz also proposed that the aether was stationary and that it was not dragged by matter moving through it, thus supporting the idea that the speed of light in a particular medium was constant and independent of the observer.

1893 JJ Thomson

Following his discovery that the mass of charged particles increased with their speed, Thomson proposed that objects would not be able to go faster than the speed of light because as their mass increased the amount of energy required to accelerate them would increase to an impossible amount.

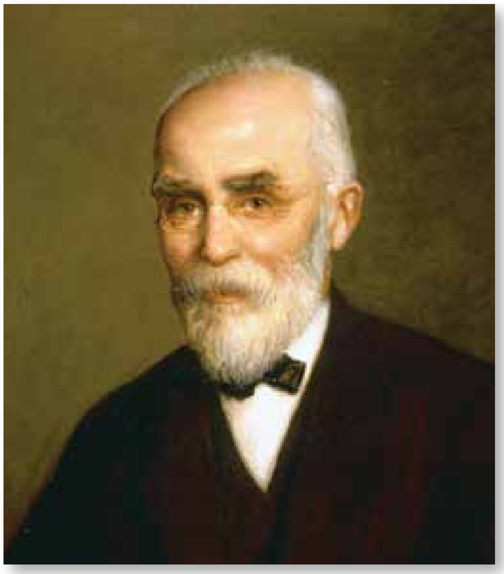
QUESTIONS

1. (a) In what way was Maxwell's idea about the nature of light different form the ideas held by other scientists of his time?
   (b) What evidence did Maxwell have for his theory?
   (c) On what observation did he base his ideas?
   (d) Was this a reasonable reason for developing a totally new theory for the nature of light? Explain your answer.
   (e) Why was Maxwell's idea about the nature of light not accepted by other scientists at the time?
   (f) What fact changed scientists' minds in that they started to take more notice of Maxwell's alternate theory for the nature of light?
2. (a) What is the distinguishing property of all electromagnetic radiations?
   (b) Later you will find that one of Einstein's postulates for his theory of special relativity is that 'the speed of light is constant regardless of the observer's frame of reference.' On the basis of your answer to (a), what would be a more correct statement of this postulate?



4 From 1895 to Einstein

1895 Lorentz



Hendrik Lorentz (1853-1928).

The controversy over the aether drag theories was resolved by the 1895 papers of Hendrik Antoon Lorentz. He published a draft version of what was to become known as the **Lorentz transformations**, in which he proposed that electrical and optical phenomena in a moving system were independent of the motion of the system provided the speeds were relatively low. In other words, the term v^2/c^2 which was included in his equations was small enough to be negligible.

This allowed a combination of electromagnetism and Newtonian physics by expanding the much simpler mathematics in Galileo's equations. He showed that when the velocities involved are much less than the speed of light, the Galilean transformations can be used to approximate the results.

With regard to fast moving objects within an aether, Lorentz proposed that since electromagnetic forces travelling at the speed of light within an object hold an object's atoms together (part of Maxwell's ideas), high-speed motion would rearrange these forces, changing the object's shape and causing a shortening (known as Lorentz-Fitzgerald contraction). Lorentz proposed a shortening by a factor of $\sqrt{(1-v^2/c^2)}$, that is $L_v = L_o\sqrt{(1-v^2/c^2)}$. This equation was later used by Einstein.

Lorentz also proposed that there would be a similar mathematical difference in the way they perceived time (time dilation) and that fast moving objects would not necessarily see events occurring at the same time as stationary or other moving objects (early version of the principle of simultaneity).

At the time Lorentz didn't realise the full power nor all the implications of his theory. In addition, he still assumed the existence of an aether. Lorentz's theory is often called the Lorentz ether theory (LET) and was criticised at the time because of its apparent random and disconnected nature. For all practical purposes however, it is the same theory as special relativity.

1898 Henri Poincaré

Jules Henri Poincaré (1854-1912).

Poincaré explained that astronomers, in determining the speed of light, simply assume that light has a constant speed and that this speed is the same in all directions.

This postulate was required in order to infer the speed of light from astronomical observations, and to judge when events that seemed to be occurring simultaneouly were analysed.

1899 Lorentz

Lorentz presented a second version of his Lorentz transformations. The reworked mathematics still indicated a time dilation and a mass increase for moving systems.

He also reaffirmed that electrical and optical phenomena in the moving system were independent of motion even if terms of the order v^2/c^2 were retained.

1900 Poincaré

Poincaré proposed that electromagnetic energy behaves like an imaginary fluid with mass density given by $\boldsymbol{m = E/c^2}$ (rearranging to form $\boldsymbol{E = mc^2}$).

He also argued that experiments like the 1887 Michelson-Morley experiment show the impossibility of detecting the absolute motion of matter, that is, the relative motion of matter in relative to the aether. He called this the '**principle of relative motion**'.

He supported Lorentz's idea that time measured by different observers isn't necessarily the same, arguing that observers don't necessarily realise this because they are unaware of their motion relative to the objects or events they are observing.

1900 Joseph Larmor

Larmor reworked and published Lorentz's 1895 transformations and stated them in an algebraic form very similar to the ones we see today. In this work he also predicted length-contraction and showed that some sort of time dilation would occur for orbiting electrons.

Joseph Larmor (1857-1942).

1902 Poincaré

Poincaré proposed that although most of the measurements we make assume that there is an absolute space and time (that is a frame of reference that was absolutely motionless relative to all other frames of reference), this, in fact, did not exist.

He extended his idea on absolute time to say that not only have we no certain knowledge of the equality of two periods of time, but we also have no certain knowledge of the simultaneity of two events occurring in two different places.

1902 Walter Kaufmann

Kaufmann was the first to show experimentally that the ratio of e/m for electrons depended on the speed of the electrons (assuming the charge on the electron remains constant at speed – note that this had been proposed by JJ Thomson nine years earlier, in 1893). As the speed of the electrons increased, the ratio became smaller. This was the first experimental proof of the idea of relativistic mass increase.

1903 Wilhelm Wien

Wien recognised an important consequence of Kaufmann's proof of the velocity dependence of mass. He argued that speeds in excess of the speed of light were impossible, because reaching them would require an infinite amount of energy.

Walter Kaufmann (1871-1947).

1904 Lorentz

Lorentz attempted to develop a theory for electrodynamics which explained all the known aether drag experiments. He tried to prove the applicability of the Lorentz transformations for all electromagnetic forces as well as for non-electrical forces. Although he did not succeed completely, possibly because he still held a belief in the existence of the aether, his work did support the idea that mass was due to electromagnetic forces. The question arose as to whether the electromagnetic theory or the principle of relative motion was correct.

1904 Poincaré

Poincaré drew some conclusions from Lorentz's theory and defined the following principle: 'The principle of relativity, according to which the laws of physical phenomena must be the same for a stationary observer as for one carried along in a uniform motion of translation, so that we have no means, and can have none, of determining whether or not we are being carried along in such a motion.'

He also proposed that no velocity, regardless of its frame of reference, can surpass that of light as measured by any observer.

With these statements, Poincaré came very close to special relativity which, in part, states that an observer in a non-inertial frame of reference can do no experiment to determine his state of uniform motion without reference to some known object outside the frame of reference.

1905 Poincaré

Poincaré published a summary of a paper which filled the existing gaps of Lorentz's work and corrected Lorentz's formulas for the transformations relating to relativistic velocity additions. On 5 June Poincaré finished an article in which he stated that there seems to be a general law of nature, that it is impossible to demonstrate absolute motion.

He proposed the existence of a non-electrical binding force to explain the stability of the electrons and to explain length contraction. He also modified the Lorentz equations to develop a wave model for gravitational forces and introduced the idea of four-dimensional space.

Later in 1905 Poincaré (independently of Einstein) finished a substantially extended work of his June paper (the so-called 'Palermo paper', received 23 July, printed 14 December, published January 1906). He spoke, among many other things, of 'the postulates of relativity'.

Most historians of science argue that Poincaré did not invent what is now called special relativity, although it is admitted that he anticipated much of Einstein's methods and terminology.

QUESTIONS

1. (a) What was the controversy that existed about the aether drag theories in the late 1800s?
   (b) How was the controversy over the aether drag theories resolved by Lorentz's 1895 work?
2. What was Lorentz's idea about electromagnetic forces and length contraction?
3. Lorentz's papers in 1895 were more significant than most that had come before then. What was it that Lorentz did that could be regarded as a 'breakthrough' in the developing ideas about relativity?
4. What was the major difference in the way the scientists involved in the development of special relativity worked compared to their compatriots in other areas of physics?
5. What was the basis of the argument put forward by Wien in 1903 to account for the hypothesis that the speed of light could never be exceeded?
6. So many changes and modifications were made to scientists' ideas about relativity especially between 1850 and 1905. What were the main reasons for these changes?
7. A particular theory explains 99 out of 100 observations about a particular aspect of nature.
   (a) Does this make the theory correct?
   (b) Should the theory be discarded? Justify your answer.
   (c) What should be the next scientific step?
8. The work above suggests there may have been something holding Lorentz's work back and limiting its direction. What might this have been?
9. Poincaré published a paper in 1905 which said 'there seems to be a general law of nature, that it is impossible to demonstrate absolute motion'.
   What do you think he meant by this?
10. In 1895 Lorentz had proposed and particularly explained (not necessarily correctly) length contraction, time dilation and the principle of simultaneity. What aspect of his work failed to direct him to the sorts of proposals Poincaré made from his work and from the very similar statements made by Einstein 10 years later?
11. Explain why relativistic effects can be ignored for objects that are travelling at normal Earth speeds. Use Lorentz's equations to support your answer.

Answers

1 Relativity in the 1600s

No questions.

2 The Aether Drag Theories

1. (a) The aether was a hypothetical medium proposed to allow the propagation of light.
   (b) Its existence was hypothesised because all other wave motions known at the time were matter waves, and so, following the pattern, it was assumed that light would also be a matter wave.
   (c) No evidence.
   (d) Aether drag is the term used to describe the effect that if matter moves through the aether, then the aether will be dragged along (either in part or totally) with the matter.
   (e) The two aether drag theories involved the partial or total dragging of the aether along with the moving matter.
2. (a) The aether wind is the effect we could measure due to the relative motion of the Earth through the stationary aether.
   (b) If the aether is totally dragged along with the motion of the Earth, then there would be no aether wind.
   (c) There would be a measurable aether wind.
   (d) The aether wind effect would be significantly larger and therefore more easily detected.
   (e) The null results of these experiments, in particular the 1887 Michelson-Morley experiment, changed the direction of the thinking of some scientists and started them looking for alternate theories about the nature of light.
3. The change in the position of distant stars relative to the field of stars beyond them is attributed mainly to the parallax shift of the star due to the Earth's different position in its orbit around the Sun relative to them.

3 Relativity 1870 to 1895

1. (a) He proposed that it was electromagnetic in nature rather than being a matter wave.
   (b) Maxwell had no direct evidence.
   (c) His idea was based on the fact that the speed of light was so much greater than the speed of any other known wave, and to him, this suggested that it might be different.
   (d) Yes. If an observation is totally different to other observations, then this could suggest the need for a totally different explanation.
   (e) It did not allow for the existence of the aether nor did it account for aether drag.
   (f) Hertz's discovery of radio waves, which supported Maxwell's proposal that light was just part of a continuous band of electromagnetic radiation.
2. (a) They all travel at the speed of light.
   (b) The speed of all electromagnetic radiations is constant regardless of the observer's frame of reference.

4 From 1895 to Einstein

1. (a) There were two main theories, that the aether was totally dragged along with moving matter and that it was only partially dragged along with moving matter.
   (b) Lorentz proposed that the aether was not dragged by matter at all and because of this, the speed of light was constant in any particular medium.
2. Lorentz proposed that, since electromagnetic forces travelling at the speed of light within an object hold an object's atoms together (part of Maxwell's ideas), high speed motion would rearrange these forces, changing the object's shape and causing a shortening.
3. Lorentz proposed that electrical and optical phenomena in a moving system were independent of the motion of the system provided the speeds were relatively low. In this way he combined ideas of electromagnetism and Newtonian physics by expanding the much simpler mathematics in Galileo's equations.
4. The development of special relativity was mainly though mathematics in an attempt to prove the existence of the hypothetical aether rather than interpreting the visible results of experiments.
5. Speed in excess of the speed of light were impossible, because reaching them would require an infinite amount of energy due to the increase in the mass of an object as its speed increased.
6. There were two main factors. Firstly, different scientists held different views on the nature of the aether and their interpretations of the developing mathematics was affected by these views. Secondly, as the mathematics became more refined, it led scientists to additional changes until ultimate versions were derived.
7. (a) No. If a theory does not explain all observations, then it is flawed in some way.
   (b) Not unless further observations or analysis show it to be completely incorrect. It may simply need minor or major revisions.
   (c) To do further experiments in the unexplained area to work towards a revision in the model (or a total change of model) so that all 100 observations are explained.
8. Lorentz still had a strong belief in the existence of the aether and was perhaps unable to let that belief go and follow the direction the mathematics eventually led Einstein. It was, after all, the same mathematics.
9. Because there is no frame of reference that is absolutely stationary, then any measurement of motion we make is not a measure of the exact motion compared to zero motion.
10. He still believed that there was an aether and that aether drag was a real property of nature.
11. From the Lorentz equations, $L_v = L_o\sqrt{\left(\frac{1-v^2}{c^2}\right)}$, at low speeds the 'Lorentz factor', v^2/c^2 approaches zero, and therefore the equation reverts to $L_v = L_o\sqrt{1}$, i.e. $L_v = L_o$. The time dilation equation contains the same factor and for the same reasons, time dilation approaches zero as speed approaches zero. Therefore relativistic effects can be ignored at low speeds.