# Modern Mathematical Science and Technology: Formalisation of the Life World

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Ciaran Summerton, B.A., Murdoch University

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# Abstract

In this dissertation, I offer a critical examination of modern science with a particular stress on the changes that the modern scientific project inaugurated. The focus is how modern science has radically changed the way we think about the world. I draw upon several phenomenological thinkers who have considered the changing nature of modern science and its relation to our present day thinking.

I begin by exploring the key differences between the Ancient Greek and modern scientific understanding of mathematics, geometry, and idealisation. Specifically, I discuss the reversal of Platonic geometry carried out by Galileo Galilei and the formalisation of Galilean physics achieved by Isaac Newton. In addition, I outline the key methodological features of modern science, which include indirect mathematisation and perfect causality, as well as the role of experimentation in the modern scientific project. Theory is central to modern science in its function of opening certain regions of things, while delimiting others. Thereby, I discuss how theory prescribes what counts as facts for science and experimentation, in advance.

Finally, I consider the pervasiveness of instrumental reasoning in modern science and technology. I conclude with a discussion of the institutional setting of modern science and its participation in business, governance, and power relations in these domains.

# Acknowledgements

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# Table of Contents

# Introduction

In this dissertation, I will argue that modern mathematical science has radically changed the way we think about the world. We live in an age in which we understand the world in techno-scientific terms. Those modes of understanding that do not follow the fundamental conceptions of modern science are rejected as illusory. To substantiate my overall thesis, I will draw on the insights of phenomenologists that continue in the tradition of Edmund Husserl and Martin Heidegger, such as Jan Patočka, Theodore J. Kisiel, Joseph J. Kockelmans, Alexandre Koyré and Hannah Arendt. I also consider and use the thought of scientists who have expressed similar ideas about modern science and its dominant role in the contemporary world.

In what follows, I will use the term modern science to refer to the classical physics that started with Galileo Galilei and Isaac Newton up until the work of Albert Einstein. It is important to acknowledge that at the latter end of the nineteenth century and throughout the twentieth century, certain aspects of the theoretical position of Newtonian physics have been questioned, but not abandoned, from within the discipline of physics. Physicists consider Newtonian physics a borderline case in a much broader domain. Hence, my contention is that the metaphysical presuppositions and methodological approaches of the modern scientific outlook have not changed from its inception through to the present day. Therefore, I suggest that much of the critique offered by the thinkers I will use is relevant to present day science.

To support my overall thesis that modern science has radically changed the way we think about the world, I will follow a phenomenological method by presenting different ways of considering how we might think about the world in which we live and how it is influenced by the modern scientific project. The aim is to show how we take scientific presuppositions for granted.

In chapter one, I discuss a number of the key methodological changes in modern mathematical science and its development, while paying attention to the way it differs from both the Ancient Greek and medieval conception of the world. In this short dissertation, I cannot do justice to this rich history, so I will sketch it in very broad outlines.[1]

I start by outlining the transition from scientific thinking in Ancient Greece through to the formalisation of Newtonian physics. I will consider the way early modern scientists such as Galileo understand the ideal formulations of geometry inherited from Ancient Greek and medieval[2] thinking. I draw attention to the following key difference: For Plato, the abstract shapes of geometry are immaterial, ideal beings. In contrast, according to the postulates of early modern science, geometrical shapes are no longer in the sphere of ideal forms; rather, we now understand them as constituting the material world. With the advent of formalisation in modern science – in which geometrical space is described purely in mathematical terms – there evolves an understanding of the world in which the two Platonic realms (one of ideal, unchanging beings and the other of the everyday world of becoming) are collapsed into an extensive formal manifold.

Then, I will survey Husserl's (1970) account of two key assumptions in the methodology of modern science, to elucidate further the change from idealisation in Ancient Greece to the formalisation in modern science. These are the assumptions of universal causality (in which all events and objects are situated within vast chains of cause and effect, each effect becoming a cause for further effects) and indirect mathematisation (the process by which qualitative experiences are correlated with quantitative determinations).[3]

In the second chapter, I extend my account of the new scientific methodology by unpacking the modern process of experimentation. The modern experiment, I argue, is not based simply on observation and a recording of facts (as is commonly claimed) but, rather, science and the modern experiment would not be possible without an *a priori* conception that posits the world as an aggregate of forces and processes in

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[1] I acknowledge that there was a large amount of thinking during the medieval period. However, in this dissertation I am interested in the fundamental changes that took place in Galilean/Newtonian physics and how these changes influenced the modern outlook. A theological reading of Aristotelian physics would be an interesting project, but I do not have the space here to go into more detail. It would require a more detailed account of the differences between Greek and Christian thinking, as well as those aspects of medieval science (for instance, Nominalism) that paved the way for the Galilean/Newtonian revolution.

[2] Medieval thought is in many ways an extension of Ancient Greek thinking, transformed through the prism of Christianity and a conception of the world with God as the ground of knowledge.

[3] See Husserl, *The Crisis of European Science and Transcendental Phenomenology*, Evanston: Northwestern University Press, 1970.

geometrical space following mathematical laws. The formal scientific system demarcates *in advance* what are scientific facts. A theoretical position is necessary in order to organise facts and observations into a science. The formal mathematical system constitutes this theoretical position for modern science.

In chapter three, following the observations about the modern experiment, I will examine Heidegger's (1978) thought on the spirit of technological thinking that permeates the modern age.[4] Heidegger's reflections on the spirit of technology highlight another aspect of my central thesis that scientific thinking in conjunction with technological advances has significantly changed the modern understanding of the world. Viewing the world technologically, nature appears as a collection of processes and forces that are open to prediction and control. Therefore, as predictable and controllable, nature is used for our innumerable projects of material expansion. By thinking about the world techno-scientifically, we encourage a relation to the world in which we believe we have the right to organise, manipulate and exploit nature for our own benefit.

Finally, in the fourth chapter I will make connections between the description of modern science (chapters one and two) and the techno-scientific understanding of the world (chapter three). This will include an account of the institutional setting of science and its relationship with business, governance, and the power relations within these domains. In addition, I suggest a more direct link between the methodological aspects of modern science and the techno-scientific understanding of the world. I will contend that the methodology of modern science presupposes a natural world of calculable, measurable and predictable processes. Thus, as calculable, measurable and predictable, natural processes become useful and can be located within the techno-scientific scheme of utility maximisation.[5]

The different emphasis and focus of each chapter provides different aspects that are necessary to substantiate my claim that modern science has radically changed the way we think about the world in the manner I illustrate throughout my dissertation.

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[4] Heidegger, 'The Question Concerning Technology', *Basic Writings*, Ed. David Farrell Krell. London: Routledge, 1978a, pp. 217-238.

[5] A more nuanced and detailed discussion is required to differentiate between scientific, technological, instrumental and utilitarian reasoning. These different kinds of reasoning are not necessarily synonymous, though they do in many ways coincide and overlap each other. Unfortunately, I do not have the space to go into these distinctions. Therefore, it may seem that I am not clearly enough distinguishing between different aspects of modern thinking.

# Chapter One:
# Formalisation in Modern Mathematical Science

Following Husserl and Patočka, in this chapter I argue that many of the changes instituted by modern science stem from the formal mathematical system thinkers such as Galileo and Newton introduced, and from which all modern science follows. Clarifying the methodological changes in this new science will help to illustrate my thesis that modern scientific thinking has radically transformed the way we think about the world far beyond the confines of the scientific community.

Eric Voegelin (1948)[6] points out that modern science has had a profound practical and social success. This success has been in large part due to the change in the way modern science uses ideal and mathematical formulations (inherited from, but understood differently by, the Ancient Greeks). The use of mathematical formulations in modern science has implications for the practical usefulness of nature because it allows for the prediction and thus manipulation of natural processes. Significantly, the mathematical formulations of modern science have also transformed the way we think about the world: we now understand nature as an extensive, mathematical manifold derived from the idealisation embedded in mathematical formulae. Such a conception would have been foreign to both the Ancient Greeks and the people of the medieval period.

In this chapter, in order to explicate the modern scientific methodology, I illustrate the key aspects of modern scientific reasoning and its relation to our everyday, experiential world by reflecting on Patočka's and Husserl's critique of mathematical science. In order to consider the contrast between the Ancient Greek use of idealisation and its modern scientific function, I will begin by illustrating the changes in thinking that took place at the constitution of modern science by starting with a short outline of idealisation as it was established in Ancient Greek thought, particularly in the work of Plato. Following this, I consider Husserl's important insight that idealisation includes also the ideas of indirect mathematisation and universal, perfect causality.

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[6] Voegelin, Eric, 'The Origins of Scientism' in *Social Research*, Vol. 15, 1948, pp. 462-494.

## Idealisation in Ancient Greece

For Plato (unlike Aristotle) mathematics and geometry had a privileged place in our knowledge of the world. Plato had this much in common with the modern science of Galileo. However, there is a key difference. Plato's reality of ideal forms, mathematical and geometric idealities, is immaterial. In contrast, Galileo considers material nature as itself an amalgamation of geometric shapes that can be described mathematically.

As Patočka argues in *Plato and Europe* (2002)[7], the use of mathematics in Ancient Greek philosophy was a response to the breakdown in the mythical understanding of the world. The Ancient Greeks sought to use mathematics and geometry as means to re-establish a harmonious and meaningful understanding of the Kosmos. In order to establish geometry as a rational science, the Ancient Greeks made use of a process of idealisation (Patočka 1989a, p.227).[8] To use an example of Plato's, we can never find a perfect triangle in the world, but seeing many different triangles in our experience, we can imagine a perfect, never changing triangle that will be the idea for the particular triangles we encounter, draw, and think in our everyday experience (Učník 2009, p.69).[9] Once the ideal triangle is imagined, Plato turns the process around and the ideal triangle becomes the unchanging reality in which all other imperfect triangles participate.

For Plato, then, the ideas are reality itself. They have unchanging being; they are not material. Only nature is the sphere of changeable beings. Plato's project was to find a secure basis that would allow us to speak meaningfully about the everyday world of becoming that is constantly in flux.[10] Therefore, our everyday world is not abandoned in Plato's philosophy; instead, 'what at first sight appears as a hopeless

[7] Patočka, *Plato and Europe*, Stanford, California: Stanford University Press, 2002.
[8] Patočka, 'Edmund Husserl's Philosophy of the Crisis of the Sciences and His Conception of a Phenomenology of the "Life-World"' (1971) in *Jan Patočka: Philosophy and Selected Writings*, Ed. Erazim Kohák, Chicago: The University of Chicago Press, 1989a, pp. 223-238.
[9] Učník, Lubica, "Husserl's Critique of the Mathematization of Nature: From *Philosophy of Arithmetic* to *The Crisis of European Sciences*", *The Far Eastern University Colloquium: The Department of Humanities and Social Sciences Research Journal*, 2009, pp. 47-79.
[10] The Greeks acknowledged that experience of the Kosmos is always imprecise and changing; whereas ideal forms – ideal reality – ordered the changing sphere of the experiential (Učník, '*Esse* or *Habere*. To Be or To Have: Patočka's Critique of Husserl and Heidegger' in *The Journal of the British Society for Phenomenology*, Vol. 38, No. 3, October 2007, pp. 297-317).

confusion' in the everyday world of changing things can now be treated with a rational and 'rigorous precision'.[11]

To consider Plato's thinking from the present, we can say that in the realm of ideal forms, each idea can be thought by anyone as identical.[12] As Husserl points out, this new kind of thinking allowed for the idealisation of units of measurement, certain privileged points, lines, and surfaces in space.[13] The Ancient Greeks produced absolute identities by establishing a formal system of ideas not susceptible to the vagaries of the everyday, changeable world. It was thus possible to 'constitute a realm of forms/beings which are not only objective but precise as well' by privileging certain units of measurement, 'ideal limit[s] which can be considered in isolation' from the experiential world.[14] Such a precise and objective idealisation, able to produce 'absolute identities', makes possible the founding of geometry as a rational science while also making possible an 'ideal of a truth-in-itself'.[15] Patočka points out that truth-in-itself becomes absolute truth, both precise and constant, because it is no longer related to the relative and fluctuating world of our everyday lives.[16]

## Idealisation in Modern Science and the New Formalisation

As mentioned above, modern science reverses the Platonic understanding of the Kosmos (as well as overcoming Aristotelian physics) by rejecting the world of becoming and replacing it with a mathematically precise universe. Formal mathematical structures constituted by our thinking (such as geometrical shapes), are projected onto nature which can thus be understood as itself an extensive mathematical manifold.[17] Hence, the ideal Platonic structure of reality is no longer understood as existing in an ideal realm but is thought to be the basic blueprint upon which the world is built and which can be accounted for by human thinking.

Husserl contends that the paradigmatic example of such a reversal can be found in the thought of Galileo. For Galileo, nature is itself geometrical, made up of shapes

[11] Patočka 1989a, p.228.
[12] Husserl 1970, p. 278.
[13] *Ibid*., p.21.
[14] Patočka 1989a, p. 227. For example, arithmetic is composed of numbers and sets that have validity for any person using the formal language of mathematics (Učník 2007, p.303).
[15] Patočka 1989a, p. 227.
[16] *Ibid*., p.227.
[17] Husserl 1970, p. 23.

that can be understood mathematically.[18] Ideals that in Plato were immaterial become material in the Galilean project because of the hypothesis (which to modern scientific thinking seems self-evident) that matter can be described mathematically. By explaining the world mathematically, Galileo hoped to overcome what he considered the relativity of subjective experience, the hallmark of our everyday, intuitive experience.[19] Similar in this sense to the Ancient Greeks, Galileo sought access to a nonrelative truth.

However, now it was a truth that could be reached only by a ‘constantly increasing approximation’.[20] In other words, scientific knowledge cannot be final but is always being improved by closer measurements and the development of more refined measuring instruments. This is because science deals with the natural world (Plato’s world of becoming) and not unchanging ideas. Scientists are continuously improving their working hypotheses, yet they will remain hypotheses. By extension, modern science also makes use of a generalising-inductive method, which arrives at results that will be altered, based on the induction of future observations.

Despite ushering in the key aspects of the modern scientific method, Galileo’s endeavour was still influenced by Plato and Aristotle. He was not able to go as far as Newton and the science that would follow; he could not conceive a natural object or process idealised, in the modern sense, to the extent that it could be thought of as completely removed from the world.[21] As Husserl suggests, Galileo’s thought still had some connection with intuition, and therefore could not operate simply in the ‘sphere of symbolism’.[22]

Alexandre Koyré has repeatedly stresses the Platonic nature of Galileo’s physics, that is, the centrality of mathematics and geometry. By returning to Plato and the use of mathematics, Galileo undermined Aristotelian physics in which mathematics did not play a leading role. At the same time, as discussed above, the use of mathematics and (geometrical) idealisation in Galileo’s science was markedly opposed to Plato’s philosophy. In trying to improve the Aristotelian system by utilising Plato, Galileo overturned both. In contrast to Aristotelian physics, the universal scope of Galileo’s

[18] Učník 2009, p. 69.
[19] Husserl 1970, p. 29.
[20] *Ibid*., p. 29.
[21] Učník 2007, p. 309.
[22] Husserl 1970a, p. 24.

and then Newton's system described laws of nature that apply equally to every domain of the world and all its objects. From then on, there is no difference between moving bodies in the sublunary region and the heavenly sphere. All regions obey the same laws of nature that Newton described. Newton and Galileo both imagine a universe following a uniform set of fundamental laws that replaces the Ancient Kosmos of Aristotle, hierarchically structured and finite (Koyré 1955, p.107).[23] Aristotle's 'concretely physically structured place-space' is displaced by Newton's 'abstract, isomorphous, and infinite dimension-space of Euclidian geometry now considered as *real*'.[24]

Galilean geometry, in which ideal shapes are thought to constitute the world, relied on a process of idealisation similar to that accomplished by the Ancient Greeks. However, by the time we arrive at Galileo's project at the beginning of modern science the process involved in transforming imprecise experience into ideal shapes had been forgotten; geometrical knowledge had been sedimented without an adequate awareness of its grounds and presuppositions. Since Galileo already described a world as if comprised of ideal shapes, Newton only needed to empty Galilean geometry of its material content in order to describe the world purely in terms of mathematical equations with the help of a complex language of symbols. Newton therefore formalises Galileo's system which was based on the reversal of the Greek process of idealisation.[25] Newton's law of inertia is not about a body in the world; it is about '*mathematical* bodies moving in *mathematical* space', that is, in geometrical space (Koyré 1943a, p.419).[26] Galileo could not take this final step beyond the world of our living. Yet, as Husserl and Patočka have shown, it was Galileo who laid the groundwork for Newton's formalisation.[27]

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[23] Koyré, Alexandre, 'Influence of Philosophic Trends on the Formulation of Scientific Theories' in *The Scientific Monthly*, Vol. 80, No. 2, February 1955, pp. 333-348.
[24] *Ibid*., p.107, italics added.
[25] Consequentially, despite Heisenberg's (1958, p.123) observation that the likes of Kepler, Galileo and Newton were still working within the medieval image of the world, however fragile, in which God was the unifying creator of the world, it was Newton who finally freed science of both the Platonic and Aristotelian heritage (Učník 2007, p.309) and, unintentionally, of the medieval conception with God at its centre.
[26] Koyré, Alexandre, 'Galileo and Plato' in *Journal of the History of Ideas*, Vol.4, No. 4, October, 1943a, pp. 400-428.
[27] Of course, Galileo had his own predecessors from within or immediately prior to the modern period (depending on where you locate it). See Koyré, *From the Closed World to the Infinite Universe*, Radford: A&D Publishing, 2008.

Following Husserl, Patočka claims that '[b]y means of the arithmetization of geometry we pass over to universal *formalization*'[28] (which is what Newton did with Galileo's project). By taking nature as itself a complex formal construct it is made accessible to the exact and precise measurements of a science 'which exhausts it methodically and systematically'.[29] In other words, by reducing nature to mathematical formal structures, by converting ideal shapes into numbers and thereby arithmetizing geometry, it becomes possible to offer a universal explanation for *all* of nature by following the mathematical scientific method. The mathematical method is expressed in equations that everybody using the method can understand as the same. The arithmetization of geometry transforms the ideal shapes of geometry into 'pure numerical configurations, into algebraic structures', so that we are led further away from the everyday world of imprecise objects that is the source of such idealisation.[30] The numerical, because it can be precisely determined, replaces the ideal shapes of geometry. We find ourselves dealing with a 'formal logic carried out universally' in the realm of 'pure thought and in empty, formal generality'.[31]

Patočka notes that it is the imprecise nature of our concrete experience that opens up the possibility of idealised concepts and scientific theorems (1989b, p.289).[32] In our experience of the world, though imprecise, we encounter regularity: typical instances of nature that we can recognise. As well as our imprecise though regular everyday experience, Patočka also considers our basic understanding of spatial relations as a key factor, giving us access to things and making idealisation (concomitantly, calculation and predictability) possible.[33] Leaving behind the imprecision of our concrete situation, the idealised mathematical realm allows us to attain exactness, 'for there is the possibility of determining the ideal shapes in absolute identity, of recognising them as substrates of absolutely identical and methodically, univocally determinable qualities'.[34] For both Husserl and Patočka, the problem is that the origins of idealisation, our imprecise concrete experience and basic understanding of space, are overlooked.

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[28] Patočka 1989a, p. 228.
[29] *Ibid*., p.228.
[30] Husserl 1970, p.44.
[31] *Ibid*., p.44-5.
[32] Patočka, Jan, 'Cartesianism and Phenomenology'(1976) in *Jan Patočka: Philosophy and Selected Writings*, Ed. Erazim Kohák, Chicago: The University of Chicago Press, 1989b, pp. 285-326.
[33] *Ibid*., p. 292.
[34] Husserl 1970, p. 27.

Husserl further explains this Galilean/Newtonian transformation of nature by reflecting upon the introduction of indirect mathematisation and universal causality into the methodology of scientific thinking.

## Universal Causality

Perfect causality is the assumption that each event must fall within an extended causal chain. The event that is an effect of past causes becomes a cause for future events. As Husserl explains, the assumption of universal causality and the relations it establishes between events 'makes possible hypotheses, inductions, predictions about the unknowns of [the world's] present, its past, and its future'.[35] From the scientific perspective, without hypotheses such as these, no progress in knowledge is possible because we would be unable to predict and therefore make use of the surrounding world.[36] Perfect causality is closely associated with the assumption of a mathematical nature and its corresponding exactitude and lawfulness.

Indeed, as I already explained above, we certainly observe regular occurrences in natural events, even without the concepts and tools of modern science. As Husserl and Patočka argue, this regularity gave rise to modern science. The behaviour, predictability, and identity of natural objects in our daily lives are 'typical' and 'approximate', following general trends, but they are never precise.[37] The typical changes and behaviour of such regularity remains inexact, though they do exhibit what Husserl calls an '*empirical over-all style'*.[38] Patočka suggests that modern mathematical science overcomes such indefiniteness by 'means of chronogeometry', by which we hypothesize that natural events are taking place only within extended chains of cause and effect.[39] Only by using chronogeometry, a formal abstraction, are we able to consider the processes and relations of nature as exactly determined, overcoming the imprecision of the world we experience through the senses. Universal causality was for Galileo, Husserl contends, a hypothesis not arrived at inductively but itself determining how we are to understand 'all induction of

[35] Husserl 1970, p. 31.
[36] The way in which the world in rendered useful via modern science and technology will be discussed in later chapters.
[37] *Ibid*., p. 25.
[38] *Ibid*., p. 31, italics in original.
[39] Patočka 1989a, p. 229.

particular causalities'; here again, the abstract hypothesis explains our concrete context.[40]

## Indirect Mathematisation

As well as universal causality, Husserl and Patočka also consider the assumption of indirect mathematisation as a key factor in the development of modern science. Similarly, to universal causality, indirect mathematisation is an assumption that modern scientists take for granted. Indirect mathematisation is the hypothesis by which scientists assume that for any qualitative datum there is a corresponding quantitative mathematical structure.[41] In order to reach a more exact measurement it is necessary that such measuring be guided by the hypothesis that it is possible to measure the unmeasurable, but also science must have at its disposal certain ideal structures (and instruments) that can be used to set up the correlation between qualitative experience and quantitative determinations.[42] Once the equivalent quantitative formulation in the mathematical realm has been ascertained, the original qualitative content can be passed over.[43]

For example, sensible experience of coldness or warmth is thought to have its *exact* numerical *correlate* in the realm of the mathematical. Qualitative experience of warmth, itself unmeasurable, is replaced by numerical determinations arrived at by using something that can actually be measured. In the case of warmth, we use a tube with mercury and measure its expansion. In the case of time, we use a clock and follow the circular motion of its hands. In both cases, units of space between numbers are being measured, not qualitative experiences of temperature or time.

The advent of digitalisation in measuring instruments has further hidden the process of indirect mathematisation and its starting point in our everyday world. For example, the traditional clock displays the process of measuring spaces between

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[40] Husserl 1970, p. 39. Scientists such as Max Planck (*Where is Science Going?,* Trans. James Murphy, London: George Allen & Unwin Ltd., 1933, p. 100) and A.S. Eddington (*The Nature of the Physical World*, Cambridge: Cambridge University Press, 1933, p. 298-99) have pointed out that the lawfulness assumed in modern science points to a statistical relation between events rather than a causal one. However, although the perfect causality assumed by the classical physics of Newton has been questioned within physics of the twentieth century, the conception of nature as a mathematical construction has remained unchallenged. Quarks, multidimensionality, string theory; none of these theories would be possible without a formal mathematical language.
[41] Patočka 1989a, p. 229.
[42] Husserl 1970, p. 34.
[43] Patočka 1989a, p. 229.

numbers from which we read the time. In contrast, the digital watch hides the process of measurement itself and simply 'reports results'.

Similarly, to read a temperature now assumes that we can provide an exact measurement, disregarding the initial correlation between originally unmeasurable experience and the instrument devised to measure it through the expansion of mercury. Likewise, using the process of indirect mathematisation we can provide not only the temperature of a body but also atmospheric conditions. If we want to check the weather, we are more likely to listen to the news or find a weather report online rather than walk outside of our houses. Numbers are taken as more reliable, which, of course, they are most of the time. Yet the process of setting our instruments in such a way that they can measure what was previously unmeasurable, in other words, indirect mathematisation between qualitative experience and quantitative determination is taken for granted.

As Husserl reminds us, we cannot directly measure our qualitative experiences because they are vague, imprecise and relative to our own personal situation. Therefore, everyday experience does not lend itself to the rigidity and precision required by mathematical concepts. Aristotle accepts this imprecision and thinks that this uncertainty should be reflected in science. Koyré explains that rather than an exacting and definitive knowledge, Aristotle believes a science needs only to 'develop its chief categories (natural, violent, rectilinear, circular) and to describe its general qualitative and abstract features'.[44] Aristotle could not imagine numbers expressing quality or motion. He asserted that we cannot use geometrical shapes to describe natural objects and this position was accepted for many centuries. For this reason, we can see the daring of Galileo's proposition that the book of nature is written in geometrical shapes and mathematical language (2008 [1634], p.183).[45] Koyré indicates that the likes of Galileo and Descartes acknowledged the impossibility of 'furnish[ing] a mathematical deduction of quality'.[46] Therefore, early modern science replaced the notion of quality, regarding it too susceptible to subjective experiences. In other words, unmeasurable qualitative experience was correlated with – and eventually replaced by – a quantitative determination of the

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[44] Koyré 1943a, p. 422.
[45] Galilei, Galileo. "From *The Assayer* (1623): [§7.1 Comets, Tycho, and the Book of Nature in Mathematical Language]." Trans. Maurice A. Finocchiaro. *The Essential Galileo*. Ed. Maurice A. Finocchiaro. Indianapolis/Cambridge: Hackett Publishing Company, Inc., 2008, 179-185.
[46] Koyré 1943a, p. 423.

natural world that was held to be objectively true for anyone using the mathematical formulations of modern science. Objective quantitative measurements, rigid and precise, became the guide to scientific knowledge.

## Conclusion

The quantitative mathematical structures allow science to predict and control future events because of the precise calculability of the mathematical realm that now stands for the changeable, imprecise world of our everyday living. For Galileo the mathematical structures that replaced qualitative experience were primarily geometric.[47] 'Warmth-vibrations' and 'tone-vibrations', or as Husserl expresses it, 'pure events in the world of shapes', are used in the language of modern science to express warmth, weight, colours and tones.[48] The qualitative is demoted to the realm of appearance.

> Thus experienced nature is displaced by a "real" nature, putatively "being in itself" and precise, which, as soon as its complex technical origin is leaped over and forgotten… comes to count as the essence which we approach asymptomatically through an infinity of hypotheses and theories.[49]

As science and its technological apparatus develop, the link between scientific hypotheses and our everyday experiences weakens. We now have a nature of 'whose qualities we know no more than the way they affect our measuring instruments' (Arendt 1958, p.261).[50] With the development of these instruments and the assumption of universal causality, the task of prediction becomes the dominating focus of a science based on indirect mathematisation. The ability to predict allows us to calculate and (presumably) control natural events.

In the ideas of indirect mathematisation and universal causality, the transition from our imprecise everyday world to the idealisations described in the hypotheses and concepts of modern science (such as ideal, geometric shapes) is overlooked. Husserl's account of the assumptions of perfect causality and indirect mathematisation highlights the trend towards formalisation that takes place in modern, mathematical science. As I have described, the success of formalisation began at the early stages of modern science when particular thinkers reversed the

[47] Patočka 1989a, p. 229.
[48] Husserl 1970, p. 36.
[49] Patočka 1989b, p. 289.
[50] Arendt, Hannah, *The Human Condition*, Chicago: Chicago University Press, 1958.

Ancient Greek notion of idealisation and projected ideal forms into the world. The method of modern science makes our understanding of nature more useful (because nature becomes more predictable and manipulable), but its elaborate conceptual framework is not nature itself.

In chapter two, to understand further the specific character of the modern scientific methodology, I consider the role of experimentation and the tendencies to objectification in modern mathematical science. Experimentation and scientific objectivity further illustrate the key changes in the new mathematical methodology. An examination of experimentation in modern science demonstrates the problematicity of claims that modern science is solely based on observation and ‘facts’. As I will argue below, the experiment is governed in advance by a particular theoretical conception of the world that restricts both the results obtained from the experiment and the nature of the hypotheses put forward. Additionally, results obtained in ideal laboratory conditions cannot be replicated in the everyday world. Considering the modern scientific conception of nature when viewed through the theoretical framework of modern science and the experimental process highlights the changes in the way we understand the world in the modern era.

# Chapter Two: Experimentation and Theory in Modern Science

In the previous chapter, I discussed the transition from the science of the Ancient Greeks to modern mathematical science. This included an account of Galileo's reversal of Platonic idealisation, and, following this, Newton's formalisation of Galileo's physics. From the Newtonian perspective, the world is seen as an extensive mathematical manifold governed by inexorable laws. Central to the presuppositions and methodological features of modern science are the assumptions of perfect causality and indirect mathematisation. My evaluation of these key features of scientific reasoning points to the consequences I mentioned above: the mathematical formulations are thought of not simply as a way of thinking about nature but as themselves constituting the world. Hence Galileo's claim that the book of nature is written in 'mathematical language'.[51]

To expand my thesis that modern science has radically changed the way we think about the world, in this chapter I further explicate the methodology of modern science by analysing the function of general laws and theoretical conceptions that pave the way for experimentation. Contrary to the typical description of modern science as based on facts and observation, thinkers such as Heidegger and Koyré have noted that modern science relies on an *a priori* conception of what the world is[52] – only from this grounding conception of the world do scientific experiments and observations follow. The theoretical framework delimits in advance what is to count as a fact. It also establishes how the facts and numbers are to be rendered intelligible and thus constitute a science. Thus, in accord with Heidegger and Koyré, I argue that modern science sets up in advance how we think about and investigate the nature. I contend that the experiments and investigations of modern science are derived from the formal, mathematical understanding of nature as established by early modern science.[53]

[51] Galilei 2008 [1623], p. 183.
[52] Namely, the world is considered as an extensive mathematical manifold following strict, determining laws. Individual forces and processes can be investigated separately and situated within the theoretical conceptions of the particular science.
[53] Although I spend a considerable amount of time in this section discussing experimentation, my main focus is on the *a priori* conception of modern science that delimits not only what kinds of questions are put to nature but also what kind of answers the investigating scientist is willing to hear.

Werner Heisenberg (1958)[54] reminds us that the experiment, as it was practiced at the early stages of modern science, was very specifically designed. Heisenberg's (and, more significantly, Heidegger's) claims about the experiment strengthen the observation made by Husserl and Patočka that in modern science we observe a growing tendency toward formalisation. The experiment in modern science is set up in advance according to a formal and conceptual framework. It is planned in order to affirm, refute, or correct a hypothesis that is formulated from within the formal structure of the mathematical model. By tailoring and arranging the experiment within a particular formal structure, and relating its results back to that structure, it relies on indirect mathematisation and presupposes the formal causality in the experimental procedure.

In this section, to make clear the idea that modern science is experimental in a very specific manner, I will present Heisenberg's (1958) account of the experiment and its objectifying tendencies in early modern science. Furthermore, I will expand Heisenberg's description by considering Heidegger's thought on the modern nature of the experiment. Following this exposition, I will suggest that the focus in modern science on mathematical laws and experimental results, derived from complex technical apparatus, both informs and marginalises our everyday experience.

## General Outline of the Experiment Following Heisenberg

Heisenberg considers Galileo's use of theoretical experimentation, in which particular natural processes are considered in isolation and explained mathematically, as setting a precedent for modern scientific method.[55] The emphasis on the experimental procedure instigated a shift in the modern understanding of nature. Nature could now be conceived as something objective, standing apart from and against us (so that it could now be rendered intelligible by a disinterested observer[56]

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In other words, the assumption that the world is an aggregate of geometrical shapes following mathematical laws and natural processes is accepted unquestioningly. This assumption precedes any particular laboratory, theoretical or field experiment. I focus primarily on physics as it has most successfully provided a precise and mathematical description of nature. It has also been successful at predicting natural events. Although other sciences (such as ecology, sociology, psychology etc.) may not employ an experimental procedure identical to that practiced by physicists, they are similarly characterised by an *a priori* conception of their object of study.

[54] Heisenberg, Werner, 'The Representation of Nature in Contemporary Physics' in *Daedalus*, Vol. 8, No. 3, Summer 1958, pp. 122-135.

[55] Heisenberg 1958, p. 123.

[56] In the sense that the scientific observer is thought to be removed from the scene they are studying. Problematically, this means that the scientific 'perspective' is objective precisely because in is not a perspectival seeing. As I have mentioned previously, scientific claims of objectivity are based on the

following the methodology of mathematical science). In other words, nature is now understood as being separate from both God and humans.[57]

The broad success of Newton's subsequent mechanics set the framework for the trend towards experimentation that would follow. Nature was no longer considered in its wholeness but was sundered into constituent parts that were viewed independently of the whole and then related back to one another via mathematical formulations and universal laws 'that hold without qualification across the cosmos'.[58] The individual experiment is a confirmation of the working of laws that apply to all bodies and processes without exception. These hypothetical laws framed and determined the focus and outcome of particular experiments in advance. Thus, claims of objective knowledge derived from the experiment rely on the process of formalisation, i.e., an elaborate language of symbols must be in place out of which hypotheses can be formulated and only then tested in the controlled environment of the experiment.

Heisenberg claims that for Galileo, and even Newton, the particular natural process being manipulated in the experiment was not yet an end in itself but was only meaningful through its relation to the whole, to truth and to God's creation.[59] However, as Voegelin reminds us, Galileo's thought experiments, in which nature was conceived as an aggregate of geometrical shapes following mathematical laws, shifted the scientists' understanding of nature so that they could claim that their description of nature is objective (that is, accessible to anyone using the formal scientific system). The objective description was thought to be independent not only of the scientist as observing subject (who became a disinterested observer) but also detached from God as the overseeing creator.[60] Nature was understood as adhering to fundamental laws: the scientist could observe these laws in isolated and controlled settings, the results of which were either further proof of the fundamental conception of nature that preceded the experiment or suggested the need for changes in the particular law or theory. As governed by precise mathematical laws, nature becomes the site of prediction; this would not be possible not possible in the Platonic

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shared methodological approach and the use of a language of symbols that can be used by any observer.

[57] *Ibid*., p. 124.
[58] *Ibid*., p. 124.
[59] Heisenberg 1958, p. 124.
[60] Voegelin 1948, p. 473.

conception of nature or in Aristotelian physics, both of which understand the everyday world to be the place of typical though unpredictable and varied instances of natural happenings.

Similarly, Martin Heidegger also considers this general characterisation of the experiment and its impetus in early modern science in a paper called 'The Age of the World View' (1976).[61]

## Heidegger and the Mathematical in the Experiment

In opposition to Heisenberg's account, Heidegger maintains that it is not the experiment that brings about the mathematisation of nature, but, rather, it is the mathematical nature of modern physics that encourages the development of the experiment that modern scientists perform.[62] It is important to stress that by the mathematical Heidegger does not mean the numerical only. Numbers are just a subset of the mathematical, as the Ancient Greeks understood it. Heidegger uses the term mathematical in a broader sense, derived from the Greek *ta mathemata*, meaning that which one knows prior to one's acquaintance with things, and that which allows one to encounter things in a particular way.[63] Modern science is mathematical in this specific sense because it begins with a complex and formal conception of what the world is (for example, in Newtonian physics) and only from this basis investigates particular objects and processes in the experimental setting. Consider the observations made above regarding the Galilean/Newtonian presupposition of laws in the experimental procedures. The experiment is conducted with the intention of verifying, disproving, or correcting a general law. Therefore, the assumption of the exact lawfulness of nature is already in place before the execution of the experiment.[64] The laws that are derived from the formal mathematical structure set out the parameters not only for future experiments but also for what kind of hypotheses will be put forward.

Accordingly, where Heisenberg sees the experiment as provoking the spread of a mathematical (numerical) conception of nature, Heidegger points out the mathematical understanding of nature both precedes and makes necessary the

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[61] Heidegger, "The Age of the World View", *Boundary 2,* Winter 1976 [1938], Vol. 340, No.55.
[62] *Ibid*., p. 345.
[63] Heidegger 1976, p. 343.
[64] *Ibid*., p. 345.

modern, scientific experiment. The experiment is mathematical for Heidegger precisely in this broader sense; it is governed by a certain hypothesis that is the outcome of speculative thinking, not derived from the things themselves.[65] Consider the hypothesis that perfect causality governs natural processes, according to the postulate of early modern science. As already discussed, in our observations of causality in everyday life, we notice that natural events display regularity. From this everyday regularity, the scientist posits a law governing these typicalities and reads them into the experimental procedure that already presupposes the law of causality and the applicability of mathematical laws to the observed regularities in the natural domain. As Richard Swinburne succinctly puts:

> Laws are not things, independent of material objects. To say that all objects conform to laws is simply to say that all objects behave in exactly the same way. To say, for example, that the planets obey Kepler's law is just to say that each planet at each moment of time has the property of moving in the ways that Kepler's law states. There is, therefore, this vast coincidence in the behavioural properties of objects at all times and in all places (1989, p.127).[66]

Likewise, Theodore Kisiel points out how the experimental procedure requires a fixed object (an object in which something permanent can be grasped and explained scientifically), one not complicated by the 'vagaries of appearance' (1970, p.178).[67] The fixed object – which, in contrast to Platonic ideals, is a material object in the natural world – is observed within a controlled setting and 'made subject to various constants and parameters', which are more suitable to the measuring techniques of the particular science.[68] As outlined above, each experiment is set up according to the theoretical conception of the particular science; for example, physicists construct the experiment differently depending on whether they are interested in the postulates of either the wave or the particle model of modern physics. A wave model experiment will be set up differently from a particle model experiment as scientists construct each experiment from a different theoretical framework.

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[65] Similarly, Husserl observes that the experimental physicist's work is oriented by abstract formulations, numerical magnitudes, and ideal poles (1954, p.48). See also Kant: 'When approaching nature, reason must hold in one hand principles, in terms of which alone concordant appearances can count as laws, and in the other hand the experiment that it has devised in terms of those principles. Thus reason must indeed approach nature in order to be instructed by it' (Kant, Immanuel, *Critique of Pure Reason*, Trans. Werner S. Pluhar, Indianapolis and Cambridge: Hackett Publishing Company Inc., 1996 [1781], B xiii).
[66] Swinburne, R.G., 'Arguments for the Existence of God' in *Key Themes in Philosophy*, Ed. A. Phillip Griffiths, Cambridge: University of Cambridge Press, 1989, pp. 121-33.
[67] Kisiel, Theodore J., 'Science, Phenomenology, and the Thinking of Being' in *Phenomenology and Natural Sciences*, Evanston: Northwestern University Press, 1970, pp. 167-183.
[68] *Ibid*., p. 178.

Prior to the experiment, the scientist removes complicating factors, and, during the experiment, imposes artificial conditions on the natural process being investigated (Fjelland 2007, p.9).[69] In Ragnar Fjelland's example of an elementary school exercise, a teacher asks the pupils to measure the boiling point of water.[70] Hardly any of the pupils achieved the commonly accepted 100C boiling point. The teacher explains the results away by giving numerous reasons for the failure to reach the 100C boiling point as due to the influence of overheated steam, impurities in the water, higher air pressure and poor experimental practice. Fjelland points out that the teacher's analysis may well be correct and that under *ideal conditions* each student would have obtained a 100C boiling point, but this example shows that in our everyday world, where we cannot achieve ideal conditions, water does not necessarily boil at exactly 100C. We cannot experience results derived from the laboratory setting in the world of our everyday living and yet we simply accept them despite our everyday experience.

Despite the incongruence between scientific explanations and our everyday experience, we understand each event in accord with *precise* and *mathematical* laws. In contrast to this type of understanding, Aristotelian physics is based on the 'observation of things, their properties, and changes under varying circumstances and conditions which, provided they are systematically performed, lead to knowledge of the way in which things as a rule behave' (Kockelmans 1970a, p.190).[71] Therefore, what counts as an observation in Aristotelian physics is markedly different from modern mathematical physics. Aristotelian physics recognises that there are 'varying conditions' in the everyday world that will alter the way things behave. By seeking 'knowledge of the way in which things as a rule behave', Aristotle acknowledged the regularity of natural events. However, to see the world as *lawful* is not equivalent to reducing all events to *precise* and *mathematical* laws that work invisibly from outside of the objects and events that are determined by these laws.

In addition to the difficulty of transmitting experimental results to the everyday world, there are also complicating factors within the experimental procedure itself

[69] Fjelland, Ragnar, 'What Ought We to Know About Science and Technology? Or: Philosophy of Science and Science Studies as Science Literacy' in *Dilemmata: Jahrbuch der Altonaer Stifung für philosophischen Grundlagenforschung*, Vol. 2, 2007, pp. 1-17.
[70] *Ibid*., pp. 7-8.
[71] Kockelmans, Joseph J., 'The Era of the World-as-Picture' in *Phenomenology and the Natural Sciences*, Evanston: Northwestern University Press, 1970a, pp. 184-201.

which would seem to challenge scientific claims of objective knowledge. As Heisenberg establishes, matter being observed in the experimental setting of physics is affected by the observation process and tools of the experiments.[72] This leads Heisenberg to claim that science cannot consider itself a body of knowledge about an objective nature but we must instead think of it as constituting our systematic knowledge of nature, not nature itself.[73] Similarly, Erwin Schrödinger asserts that 'light waves do not really exist, they are only waves of knowledge' (2000 [1956], p.1065).[74] In other words, the complex formulae, theoretical speculations and accrued experimental data are schematised and arranged in a way that allows us to interpret or think about the world in a particular way. However, as Plato realises, idealisations developed in our thinking do not constitute the everyday world, though they can make it more intelligible and useful.

Despite the acknowledgement made by particular scientists of the metaphysical starting point of conceptual scientific knowledge, the basic outlook and presuppositions remain largely undisputed. For instance, we still think of nature as an extensive mathematical manifold. The methodological assumptions of Galilean and Newtonian science also remain unquestioned: scientific studies are causal analyses; qualitative experiences are sidelined in favour of quantitative, numerical determinations; nature is studied not by observations in our everyday world but in the controlled setting of the experiment. These fundamental methodological positions persist to the present day.

## Theory in Modern Science

The way the methodological framework governs modern scientific thinking and investigation can be captured by again considering Heidegger's notion of the mathematical nature of modern science. Prior to both theoretical speculations about specific phenomena and experimentation, modern science is underpinned by fundamental assumptions about how the world works; for example, in Newtonian physics, the world is thought to adhere to strictly causal laws; this assumption directs all further investigations of Newtonian physics. This *a priori* conception of nature is characterised by the mathematical in the broader sense, i.e., it sets out in advance

[72] Heisenberg 1958, p. 134.
[73] *Ibid*..134.
[74] Schrödinger, Erwin, 'Causality and Wave Mechanics' in *The World of Mathematics*, Vol. 2, New York: Dove Publications, 2000 [1956], pp. 1056-1068.

how an object is to be encountered, and which objects can be considered as the only possible objects of observation.[75] In Newtonian physics it is only as 'spatiotemporal kinetic events', that is to say, as mechanical movement, that events are considered as events at all.[76] The success of a modern science such as physics and the application of its methods to ever-wider areas are at odds with our daily experience in which we do not encounter things simply as spatiotemporal kinetic events.

It is typically considered that modern science is based on observation and experience as opposed to speculative thought. However, as Koyré contends, a collection of facts observed and experienced is not a science until the facts have been 'ordered, interpreted, [and] explained' (1968, p.89).[77] In other words, those facts are already read through the 'mathematical method': facts are observed only with the guidance of regularity and law. In this way, science can overcome the twofold difficulty of counting and measuring. Firstly, our qualitative experiences do not lend themselves to rigid, precise and universally determined measurements. Therefore, in modern science, the qualitative is correlated with quantitative determinations (as in the process of indirect mathematisation described above), which guarantees a universal determination in which anyone following the mathematical methodology will arrive at identical results. The second difficulty is that the objects and events in nature are constantly in a state of flux and change (i.e., physics is itself a theory of motion). In order to be useful and determinable by scientific knowledge there must be something permanent in nature that science can grasp. In order to get hold of its object, modern science 'must bring this motion to a standstill and nonetheless maintain it as motion', as Kockelmans expresses it.[78] This leads us back to Heidegger's observations about the theoretical grounding of the modern experimental procedure. The laws and facts only find their determining relation with the assistance of (mathematical) theories (Kockelmans 1970b, p.162).[79] The 'facts' acquired in the modern experiment are derived from measuring instruments which supply us with numerical determinations of that which is under investigation (relying on the process of indirect mathematisation and the assumption of perfect causality). The facts (as numbers)

[75] Heidegger 1976, p. 343-4.
[76] Heidegger 1976, p. 344.
[77] Koyré, Alexandre, 'An Experiment in Measurement' in *Metaphysics and Measurement: Essays in Scientific Revolution*, Cambridge, Massachusetts: Harvard University Press, 1968, pp. 18-117.
[78] Kockelmans 1970a, p. 189.
[79] Kockelmans, Joseph J., 'Heidegger on the Essential Difference and Necessary Relationship Between Philosophy and Science' in *Phenomenology and the Natural Sciences*, Evanston: Northwestern University Press, 1970b, pp. 147-166.

reinforce the mathematical projection of nature as a set of numerically describable forces and laws. The interpreting of facts requires that a theoretical attitude be adopted.

As Koyré and Heidegger argue, our everyday experience is much better described by Aristotelian physics. Yet, modern science disregards the importance of this common experience. The observation and experience of modern science cannot take place in our daily lives, because its experiments can be performed only in the controlled setting of the laboratory. The experiment, as outlined above, must be determined in advance by a particular hypothesis. Thus, as Arendt observes, there is circularity in modern experimental science: 'scientists formulate their hypotheses to arrange their experiments and then use these experiments to verify their hypotheses'.[80]

At the early stages of modern science, when Newton and Galileo were establishing their physics, the hypotheses themselves were derived from speculative thinking within a particular theoretical framework; that framework is now largely unquestioned. Therefore, hypotheses are now derived from the formal system established at the beginning of the modern era. The experiment and the theory grow in 'precision and refinement' together.[81] However, it is the theoretical position that sets the parameters for the particular scientific enquiry. As Koyré notes, '[g]ood physics is made *a priori*. Theory precedes fact' (1943b, p.347).[82] Our everyday experience 'is useless because before any experience we are already in possession of the knowledge we are seeking for…'.[83] In other words, the fundamental laws of modern science were originally established *a priori* in theoretical reflection; now, the fundamental laws are simply taken as the givens that constitute the formal framework of any scientific investigation or claim.

Part of the *a priori* framework of modern science includes presuppositions such as universal causality and indirect mathematisation. Both are central to modern science precisely as *metaphysical* positions upon which science rests. Without these presuppositions, there could be no science, as we now know it. Consider the principle of inertia, the fundamental starting point of Newton's system. This

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[80] Arendt 1958, p. 287.
[81] Koyré 1968, p. 90.
[82] Koyré, Alexandre, 'Galileo and the Scientific Revolution of the Seventeenth Century' in *The Philosophical Review*, Vol. 52, No. 4, July, 1943b, pp. 333-348.
[83] *Ibid*., p. 347.

principle states that 'a body, left to itself, remains in its state of rest or of [rectilinear uniform] motion as long as it is not interfered with by some external force'.[84] There is no possibility of such a body existing because there is nowhere it could exist or move. An infinite rectilinear uniform motion is impossible in the world of our everyday living; such a motion can only be imagined in theoretical reflection that accepts the presuppositions of modern science.[85] Inertial motion is, and must remain, a hypothesis that contradicts ordinary experience. Gravity too is a hypothesis that is universally accepted yet remains a hypothesis that reflects the 'vast coincidence in the behavioural properties of objects at all times and in all places', as Swinburne describes it.[86]

In short, universal causality, indirect mathematisation, the principle of inertia and the concept of gravity are all examples of the mathematical element of modern science in the Heideggerian sense. Our understanding of the world is determined in a way not derived from experience, neither in the laboratory nor in the everyday world. In scientific reasoning, the mathematical understanding comes before and restricts both the domain of science and our everyday experience by delimiting possible objects of investigation to those that can be measured, calculated, and incorporated in the formal system of mathematical laws. The presuppositions of classical physics shape how we think about the things we encounter in the world.

Based on the presuppositions of modern science we pass over the imprecision of the Aristotelian position, which does not allow us to predict natural occurrences. We now explain matter, motion and forces mathematically, which in turn reinforces the development of the language and methodology of natural science. Clearly, this is not simply a pragmatic approach but a defining philosophical position. Koyré refers to the philosophical attitude of modern science as '*mathematical realism*'.[87]

## Privileging of Formal Schemas Over Lived Experience

As outlined above, the formal structures of modern science described in the language of mathematical realism, to use Koyré's terminology, are no longer understood as ideal constructs produced by human thought, but are considered as nature itself,

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[84] *Ibid*., p. 334.
[85] Koyré 1968, p. 3.
[86] Swinburne 1989, p. 127.
[87] Koyré 1955, p. 111, italics in original.

subsequently discovered through the scientific method. This modern scientific perspective has altered the way we think about our practical experience of the world, separate from scientific knowledge and its technological apparatus.

The developments in scientific and philosophical thought at the beginning of the modern period were accompanied by a general distrust of the senses that constitute our daily experiences. Voegelin sees Newton's attitude as the paradigmatic example of such suspicion towards our sensory experience.[88] Newton claims that we 'ought to abstract from our senses, and consider things themselves, distinct from what are only sensible measures of them'.[89] Sensible measures are not uniform and, therefore, cannot be used for precise predictions. For Newton, sensible experience can access only the images of things; direct experience is here reduced to mere appearance; only scientific formulas and tools can access things as they truly are, i.e., constituents of matter acting in accord with universal laws and invisible forces. As Arendt notes, 'the goal of modern science… is no longer to augment and order human experience… it is much rather to discover what lies *behind* natural phenomena' (1968a, p.267, italics in original).[90] This distrust of sensory experience and the corresponding attempt to access 'what lies behind natural phenomena' was exacerbated by technological inventions such as the telescope and the microscope, which showed us aspects of the world different from our daily experience.

Despite objections made by Berkeley and Leibniz, Newton's system and his methodological approach provided impetus for the further development of the approaches in modern mathematical science because of its ability to predict natural events.[91] According to Heisenberg, this necessitated a change in the very understanding of what nature is; nature became that which is brought to light by scientific formulae and technology, apart from what we might encounter in direct experience.[92] As far as modern science is concerned, daily experience becomes a mere appearance of the processes that are discovered through the scientific method: the world becomes composed of matter and forces that are taken as the intrinsically real. Now, even matter is dissolved into electrical charges understood as either waves

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[88] Voegelin 1948, p. 469.
[89] Newton quoted in Voegelin 1948, p. 469.
[90] Arendt, Hannah, 'The Conquest of Space and the Stature of Man' in *Between Past and Future: Eight Exercises in Political Thought*, New York: The Viking Press, 1961a, pp. 265-282.
[91] Voegelin 1948.
[92] Heisenberg 1958, p. 124.

or particles, depending on the model used to 'read it'. The focus on material nature in the nineteenth century led to the development of atomistic, materialist science in which atoms were taken as the 'unchanging building stones of matter'.[93] Therefore, the later discovery of a subatomic level consisting of protons, neutrons and electrons, and the further discovery of force fields (for example, electrical force fields) did not fundamentally challenge the atomic, materialistic world-view. The subatomic level still takes matter as the truly real, only it breaks it down into smaller constituents; force fields were considered only in their relation to the atomic, to the material, and were still considered to operate in accord with mathematical laws in space and time.[94]

The adventures in scientific idealisation (which Newton formalised and expressed in a language of symbols) make the technical mastery of nature possible, though, as Arendt claims, no more intelligible for us. As Arendt contends, in the modern age and as a result of scientific advances, we risk finding ourselves in a situation where we 'will forever be unable to understand, that is, think and speak about things which nevertheless we are able to do'.[95] In other words, nature is described in equations and symbols that physicists can manipulate freely following the rules of the system (allowing for the prediction and manipulation of natural objects and processes), without being able to convert those results into the language of our everyday world.

Therefore, modern science informs our experience and thinking about the world while simultaneously displacing those experiences that are incompatible with scientific methods and language. Modern science does this by elevating formal structures, ideal constructs, and technologically assisted observations to the level of the truly real, which is now used to explain our everyday experiences. Patočka contends that because of the success of science and technology – involving an explanation of nature using the mathematical methodology – we accept the scientific perspective uncritically. We now believe that we find reality itself within this mathematical realm, 'with the directly given human context explained away for the

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[93] *Ibid*., p. 125. Of course, materialism had its representatives in Ancient thought, for example, in the atomism of Democritus. However, Democritus' philosophy differs in both its conception and its purpose from modern materialism. See Patočka *Plato and Europe* (2002), particularly 'Clarity and Blind Wandering in the Mythical world – The Birth of Philosophy as the Explicit Question Face to Face with the Original Manifesting of the World – The Pre-Socratics'.
[94] Heisenberg 1958, p. 126.
[95] Arendt 1958, p. 3.

most part as its "appearance"' (1989c, p.329).[96] Albert Einstein finds this attitude expressed primarily in the theoretical physicist, for whom 'the constructions of his imagination appear so necessary and so natural that he is apt to treat them not as the creation of his thoughts but as given realities' (2009, p.300).[97] For the likes of Husserl, Heidegger, and Patočka, the trend toward formalisation and the resulting displacement of everyday experience has brought about an existential crisis that reaches beyond the domains of science and philosophy and permeates all aspects of modern life.

## Dangers of Formalisation, Consequences for Our Understanding

Husserl considers the specialisation of modern science dangerous because the one-sided approach of mathematical science is taken as knowing the totality of things[98], sidelining other ways of reflecting upon and investigating the world. The one-sidedness Husserl is referring to means that each of the modern sciences shares a similar theoretical position: in modern mathematical science, the world is understood as nothing but mathematically describable matter, motion and forces following general laws. In light of the increasing specialisation, Husserl warns that 'no line of knowledge, no single truth may be absolutized and isolated'.[99] In modern mathematical science, we face the possibility of such an absolutising knowledge. The danger of specialisation is that chemistry, biology, physics, or whatever branch of modern science, are studied independently of a philosophical consideration of their own grounds. Forgetting its metaphysical grounding, science proclaims its independence from philosophy. Once operating autonomously, science can surge ahead with its projects of formalisation, universal theory of phenomena, and domination of the natural world without reflecting on its fundamental assumptions or the consequences of its application to the world in which we live. Accordingly, the success of modern science has encouraged the development of a technical efficacy and increased formalisation that is no longer connected to a responsible reflection on its grounds, which reside in the pre-theoretical world of everyday living. It also

[96] Patočka, Jan, 'The Dangers of Technicization in Science According to E. Husserl and the Essence of Technology according to M. Heidegger' (1973) in *Jan Patočka: Philosophy and Selected Writings*, Ed. Erazim Kohák, Chicago: The University of Chicago Press, 1989c, pp. 327-339.
[97] Einstein, Albert, 'On the Method of Theoretical Physics', *Philosophy of Science: An Historical Anthology*, Eds. Timothy McGrew, Marc Alspector-Kelly and Fritz Allhoff, Chichester: Wiley-Blackwell, 2009, pp. 300-303.
[98] Husserl 1970, p. 291.
[99] Husserl 1970, p. 291.

ignores its boundaries, both in terms of claims to knowledge and ethical considerations in the scope of research. Finally, modern science's purpose is also unquestioned; science is now oriented towards mastering nature as opposed to making the world and human life more intelligible.

Patočka agrees with Husserl's explication of one of the great contradictions of our epoch:

> Science, the vital foundation of our life as a community, without which mankind [*sic*] could simply not survive in the industrial age, lies at the same time at the roots of the emptiness of modern life, of its anonymization, of the draining of all tangible meaningfulness in a bottomless abstraction.[100]

Husserl and Patočka both acknowledge the importance of science for the contemporary human world and our very survival. However, they are concerned with the dominating mathematical formalisation that drains meaning from our understanding of the world in which we live (precisely because everyday meaningfulness cannot be formulated in mathematical language) without providing a sufficient substitute. The particular tree or rock I encounter in the everyday world, described at its molecular, chemical, or (sub)atomic level is no longer that tree or rock which has a significance for me that is outside of mathematical abstractions. To view the world in terms of forces and the smallest constituents of matter, an aggregate of objects pieced together, predictable, controllable and manipulable, encourages a relation to the world in which we take ourselves as being given the right to use and exploit those objects and forces. When we move within the abstract mathematical realm, we forget that those abstractions are about the world in which we live.

As Heidegger and Patočka suggest, the forever expanding reach of modern science includes human beings also as forces and matter, controllable, predictable and manipulable, to be used and organised. How else could a purely mathematical understanding consider the world, the natural, the human? There is no *ought* in mathematical formalisation. Nor is there any reflection 'on value, on perfection, on harmony, on meaning and on purpose'.[101] Modern mathematical science, by itself, has nothing to say about morality, and in an age when its dominance is unchallengeable, the moral foundation of our human existence is threatened. Without

[100] Patočka 1989a, p. 233.
[101] Koyré 1943a, p. 404.

ethical reflection, not only human life but also the world itself is threatened, as we are now experiencing in the environmental crisis.

Husserl and Patočka maintain that the dominance of scientific, formalised knowledge is weakening our ability to use other ways of thinking. Exacerbating this decline in non-scientific reflection is the contention that only scientific reasoning is 'rational', or, is reasoning at all; other modes of reflection are relegated to the sphere of the non-rational. Therefore, we need to re-think and broaden our conception of reason in order to reinstate the credibility of moral reasoning and other forms of non-scientific reflection.

Similarly, to Husserl and Patočka, Voegelin is concerned by the neglect of the experience of the spirit in the modern age.[102] The scientific worldview has replaced the religious order of the soul without being able to fulfil certain moral and spiritual requirements for a genuine humanity[103]. Metaphysical questions are neglected precisely because such questions cannot be accounted for within the scientific framework (although modern science is itself based on metaphysical ideas).[104] As Voegelin expresses it, the modern scientific perspective is characterised by the attitude that 'all reality which is not accessible to sciences of phenomena is either irrelevant or, in the more radical form of the dogma, illusory'.[105] Pressing existential concerns such as what is the good life and how we ought to pursue it are neglected to the spheres of the irrelevant and the illusory.[106]

## Conclusion

In this chapter, and as an extension of my account of the new scientific methodology, I unpacked the process of experimentation. The modern experiment, I argued, is not based simply on observation and a recording of facts (as is commonly claimed) but, rather, is derived from an *a priori* conception that sees the world as an aggregate of forces and processes in geometrical space following mathematical laws. The formal scientific system establishes in advance what is to count as a fact. Only from this

[102] Voegelin 1948, p. 462.
[103] Similar concerns are expressed by scientists themselves. See, for example, Planck, *Where is Science Going?* London: George Allen & Unwin LTD, 1933.
[104] Explicit metaphysical questions are neglected because it is assumed that we have ascertained the nature of things, or, at least, the method necessary to study this nature. Thus, the metaphysical position of modern science goes unnoticed.
[105] Voegelin 1948, p. 462.
[106] See also Gurwitsch, Aron, "On Contemporary Nihilism", *The Review of Politics*, April 1945, pp. 170-98.

theoretical starting point can the ‘facts’ be organised within the already established and systematic science.

> The assumptions of perfect causality and indirect mathematisation are central to the modern experiment; experimental analyses are causal, and the facts they use are derived from measuring instruments that function on the basis of the process of indirect mathematisation.

Significantly, the mathematical description of nature and the measurements and observations made with the assistance of sophisticated technical machinery are now considered as the world itself; our everyday experience is thought to be merely the appearance of the underlying reality which science uncovers.

In the following chapter, I consider the relationship between technology and science in the modern period. The technological bent of modern thinking reflects one particular aspect of the way modern science has significantly changed the way we think about the world. Following Heidegger, I argue that modern science and technology are part of the broader understanding of the world that characterises the modern period; namely, the world is seen as particular instances of measurable and calculable (and, therefore, useful) objects, forces and processes.

# Chapter Three:
# Heidegger and The Essence of Technology

In the previous chapter, I discussed the relationship between scientific investigation and the theoretical framework already in place that governs both experimentation and the hypotheses considered for investigation. This led me to emphasise the importance of conceptual and methodological presuppositions in modern science.

If, as Patočka, Husserl, Voegelin and others claim, scientific methods and concepts cannot account for our lives as we experience them or the existential situations we encounter daily, then it would seem reasonable to assert that such questions become secondary (or are considered personal matters) in an age dominated by scientific thinking. Additionally, in an age in which knowledge is typically equated with scientific knowledge, the world as we experience it, live in, are responsible for, and must make choices about, is sidelined in favour of the scientific, formal picture of the world. In what follows I will expand on the account of scientific thinking given in chapter one and two by introducing Heidegger's reflections on technology as outlined in his essay 'The Question Concerning Technology' (1978a) in order to illustrate the way in which modern humans view the world aided by scientific categories. I will suggest that the scientific perspective and the growth of technology have encouraged a relation to the world in which we consider it a resource for our projects of material expansion. Thus, Heidegger's thought on technology shows another aspect of my overall thesis that modern science has radically changed the way we think about the world.

Heidegger's interest in technology has little to do with particular technological apparatus or the development of technical instruments, tools and processes. Rather, Heidegger is interested in what he refers to as the *essence* of technology. As he repeatedly stresses, the essence of technology is itself nothing technological. Hence, the problem is not technology itself. Rather, it is the way we use technology. We are blind to the techno-scientific categories we employ when we evaluate the world in scientific terms and work upon it with advanced technology.

Heidegger stresses the propensity in the modern period to evaluate particular objects and processes in terms of their utility. He considers both science and technology as central components of the modern conceptualisation of the world, which investigates particular regions of phenomena in order to derive the maximum benefit from that particular grouping of forces and processes. Nature is considered only to the extent that it conforms to the lawful and mathematical conceptions modern science presupposes because, as a lawfully determined and mathematically describable configuration of entities and processes, nature can be made useful to the growing desires and unrestrained expansion of modern civilisation.

In order to consider the account of modern science given in the previous chapters from Heidegger's reflections on the technological understating of the world, I will first explicate in greater detail what constitutes the techno-scientific understanding.

## The Essence of Technology

Heidegger contends that technology is a way of revealing.[107] In other words, technology brings forth certain aspects of the material nature it works with (defined in terms of the scientific perspective outlined earlier) that were previously concealed. This is achieved, for example, in modern science, by using the experimental procedure described above: individual forces and processes are isolated and rendered useful by their conversion into mathematical quantities and laws, which allow for prediction. Similarly, technological innovations such as the power station allow people to isolate and store energy from a particular region of the natural world. In both instances, lacking is an acknowledgement of the relation between the particular phenomenon being investigated and the world in which it is situated, and a grasping of the fact that it is the world we live in, must continue to live in and care for that we are studying and manipulating.

In support of my general thesis, Heidegger contends that the way the world is understood via modern science and technology shows the world to us in a very particular way. The world is understood as a vast resource to which we not only have access but also the right to make use of for our projects. As outlined above, scientific thinking (in mathematical symbols and formulae) does not include a reflection on our responsibility for the surrounding world. A technological way of reasoning primarily concerned with optimising opportunities for controlling nature and increasing

[107] Heidegger 1978a, p. 222.

material well-being is blinded to the impact its contemporary projects may have on the future of the world.

Devoid of these kinds of reflections, Heidegger claims that the revealing of modern technology challenges nature.[108] By 'challenging nature' Heidegger is suggesting that modern technology (and science) first investigate and then work upon nature in order to secure a supply of energy and resources that can be accumulated and stored so as to be on-call when their use is required. In order to be ready when called upon, the energy and resources unlocked must be transformed into something storable. Thus, with the use of technology and the scientific methodology, nature is set upon so that what was previously contained (for instance, energy in coal) can be exposed, unlocked, and made useful. That which is unlocked and exposed is captured in a broader project that attempts to maintain 'the maximum yield at the minimum expense'.[109]

Acting upon nature in this way highlights the mode of understanding that operates as the essence of technology. Its complex and interlocking paths require a controlled and regulated system of integration. The regulating works by constructing a system of storage in which everything is on standby and ready for when it may be needed for some particular purpose. Heidegger calls that which is placed on standby in this mass system of extraction and ordering the 'standing-reserve'.[110] When we think technologically, we order the standing-reserve in such a way that is bereft of any higher aim or purpose; under the technological attitude 'our only goal is optimal ordering for its own sake' (Dreyfus and Spinosa 2003, p.342).[111] In other words, the new techno-science is without a specific end: whereas the windmill was bound to follow the rhythm of climatic conditions surrounding it, the power-plant operates by continuously extracting energy so that it can endlessly remove and store energy without being limited by particular goals or worldly conditions.

As a result of the way we understand the world with the aid of modern science and technology we come to see our surrounding world in a new way. We now encounter the world as isolated deposits of energy and material that we use to secure and

[108] Heidegger 1978a, p. 223.
[109] *Ibid*., p. 224.
[110] *Ibid*., p. 225.
[111] Dreyfus, Hubert L., and Charles Spinosa, 'Further Reflections on Heidegger, Technology, and the Everyday', *Bulletin of Science, Technology and Society*, 2003, Vol. 23, No. 339.

expand the human artifice. For instance, the land becomes a mining district from which to extract its natural minerals and resources.[112] The extracted resources (for example, coal or oil) are then used to run generators at power stations whose purpose is to store and distribute energy across vast spaces of human inhabited land.[113] Farming no longer revolves around simply placing grain in the soil and making use of the natural process of growth. It now involves a 'mechanised food industry'[114] based on altering natural material and processes, combined with vast systems of storage and distribution. Similarly, the hydroelectric plant is not a mere continuation of natural workings but instead captures and alters those natural workings so the river may become 'dammed up into the power-plant' so as to supply water-power.[115]

Arendt gives a similar account to Heidegger. She observes that by extracting and altering natural processes and thus starting processes of our own (as in the case of nuclear energy) we have gone far beyond the pre-modern age which merely exploited natural processes without altering or storing them (for example, the windmill). We have also taken this process further than the industrial age 'where natural forces were imitated and utilized as man-made means of production', as in the case of the steam engine (1961b, p.58).[116] Similarly, Heisenberg points out that the technology of the early industrial period mostly 'imitated the actions of man's hands' and was thus largely an extension of traditional forms of craftsmanship.[117] In the industrial era, nature was still the material for the human artifice; it was not itself taken as something to be acted into and thus itself integrated into the expanding human artifice, seemingly without limit, as Arendt claims has happened during more recent times in our increasingly technological world.[118]

Arendt describes this new approach to nature as an 'acting into' nature. It involves using natural forces (for instance, those stored in coal or atoms) to fulfil the work previously performed manually.[119] For Arendt, such acting into and starting,

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[112] Heidegger 1978a, p. 223.
[113] Kisiel 1970, p. 180.
[114] Heidegger 1978a, p. 224.
[115] *Ibid*., p. 224.
[116] Arendt, Hannah, 'The Concept of History: Ancient and Modern' in *Between Past and Future: Eight Exercises in Political Thought*, New York: The Viking Press, 1961b, pp. 41-90.
[117] Heisenberg 1958, p. 127-8
[118] Arendt 1961b, pp. 58-9. However, though it manifests itself in different ways, I believe Heidegger would contend that the technological understanding of the world is present throughout the entire modern era, during both the industrial period and throughout the 20$^{th}$ century. Arendt's observations highlight the intensification of technological thinking.
[119] Heisenberg 1958, p. 128.

exploiting or altering natural occurrences is a result of the development of the notion of processes.[120] If nature (and history with it) is seen primarily as a configuration of processes then it becomes accessible to human interference[121]. The distinction between 'starting a process' in human affairs and acting into and starting processes in nature has collapsed. By acting into nature in this way, we bring into the natural realm the contingency and unpredictability of human affairs. Thus, our world in its natural and human aspects is increasingly exposed to 'an endless new chain of happenings whose eventual outcome the actor is utterly incapable of knowing or controlling beforehand'.[122] Arendt further contends,

> The moment we started natural processes of our own – and splitting the atom is precisely such a man-made natural process – we not only increased our power over nature, or became more aggressive in our dealings with the given forces of the earth, but for the first time have taken nature into the human world as such and obliterated the defensive boundaries between natural elements and the human artifice by which all previous civilisations were hedged in.[123]

In order to 'act into' nature the way Arendt describes, a scientific and technological perspective must be adopted in which particular processes are mastered and manipulated so that they may serve the growing demand that nature always be somehow useful to human purposes. Consequently, the relation of the particular to the whole and the impact on the world being 'acted into' is not at the forefront of our considerations when dealing with things solely from a techno-scientific perspective. In addition to our forgetting the potentially disastrous[124] effects of treating nature as particular instances of useful material, the techno-scientific perspective also precludes an awareness of the consequences of a technological understanding of the world on human beings themselves.

In the modern world organised by science and technology, surrounding the primary process of unlocking, extraction and alteration of natural happenings is a network of storage, distribution, regulation and consumption. This network includes the interlocking relationships between, for example, the industry of agriculture or that for

[120] Arendt 1961b, p. 58.
[121] For Arendt, the notion of process was derived from both the experience of fabrication (e.g., following a plan to build a house) and the experience of starting something new that takes place in the sphere of human affairs (e.g., the unknown consequences of a political act).
[122] Arendt 1961b, pp. 59-60.
[123] *Ibid*., p. 60.
[124] The techno-scientific project of modernity is self-defeating: it undermines the very base (nature) on which it hopes to support itself; in attempting to perpetuate human survival, it threatens the very existence of civilisation.

commercial woods, the governments of the interested industries and the chains of distribution that connect with individual consumers. As well as regulating the functioning of primary industry, the technological spirit also organises the flow of information and the interlocking of markets. Kisiel notes that the system erected to assure the functioning technological project permeates far beyond our relationship to nature's hidden possibilities.[125] In fact, the regulating and organising character now has a global reach as can be observed in 'planetary networks of communication, transportation, industrial organisation, international monetary funds, etc.'.[126] Kisiel observes its cybernetical character

> in the problems of ground and air control of traffic, logistical control of contingencies through insurance plans, polls, weather forecasting… ecological control of pollution, conservation of natural resources, and population control.[127]

The vastness of the planetary project of utility maximisation and organisation and its adherence to the techno-scientific mode of reasoning precludes any reflection on the possible consequences or the very purpose of such mass organising and securing. Once the techno-scientific mode of understanding the world (and humans as part of it) is sedimented, it is difficult to introduce other ways of reasoning without being accused of irrationality or anachronistic thinking.

Indeed, Heidegger acknowledges that the technological complex also includes humans as resources from which to derive the maximum benefit for the system (for example, paying low wages in order to attract foreign capital). Paradoxically, humans become mere means in a process whose purpose (end) is supposedly the improvement of the human lot. If we have become masters of the world, it was at the price of finding ourselves incorporated into a planetary system that makes no distinctions and evaluates things (including humans) solely in terms of their expediency and efficiency.

As humans are themselves among the objects to be organised and utilised it follows that they can also be studied using the same principles and methods as other natural objects. The application of the natural scientific method to human life assumes a removed and impartial observer able to consider the situation he/she gazes upon objectively. In other words, studying human interaction would be no different from

[125] Kisiel 1970, p. 180.
[126] *Ibid*., p. 180.
[127] *Ibid*., p. 180-1.

observing the celestial bodies or a society of bees because ‘physical and social phenomena would appear in the same light’ (Hayek 1941, p.12).[128] Humans are studied naturalistically because it is hoped that from this perspective they will display regularities of behaviour that allow for prediction, manipulation and control so that we can manage and determine ourselves with an exactitude not far removed from the mathematical exactitude to be found in the laws of classical physics.

Therefore, Heidegger contends that the modern era ushered in a *transformation in meaning* that has changed the status of humans as well as the natural world. As Patočka points out, Heidegger’s concern is not simply related to the replacement of our life-world by formal generalities, which came about because of changes in scientific and philosophical thinking.[129] Heidegger sees the problem ultimately in the transformation of our life-world ‘in its factual state and meaning’.[130] The techno-scientific understanding of the modern age determines the meaning of both things and people by placing them within a universal system of utility maximisation. For example, under the sway of the technological spirit, the modern aeroplane is no longer understood as an object or tool. Rather, it is a mechanical component in the larger transportation industry. The passengers on the aeroplane are no longer individuals but ‘resources recruited by the tourist industry to fill the planes’.[131] The tourist industry is also a resource or cog in a broader system of industry and governance.

> Thus apparently autonomous units are integrated into a vast network of relations in which they function rather than dwell, have an affect rather than repose, though in this sense they are: the very meaning of their being has been transformed.[132]

Consider the scientific methodology outlined above in which the world was broken up into particular forces and processes that are transformed into formal units as part of the broader scientific system. These particular parts are not considered as meaningful phenomenon we encounter in daily life but solely as aspects that must somehow find their place within the scientific mathematical construct. The example of the aeroplane, the passenger and the tourist industry given above illustrates the

[128] Hayek, F.A. von., ‘The Counter-Revolution of Science’, *Economica*, New Series, Vol. 8, No. 29, Feb. 1941, pp. 9-36.
[129] Patočka 1989c, p. 330.
[130] *Ibid*., p. 330.
[131] Dreyfus and Spinosa 2003, p. 341.
[132] Patočka 1989c, p. 330.

way in which we have transplanted this kind of reasoning and organising to human life.

The transformation of the meaning of a particular object, institution, or life, can be highlighted by considering the Ancient Greek or Christian period. For the Greeks, the particular only made sense in relation to a meaningful and harmonious whole. Plato attempted to live a life and establish a communal situation governed by reason that would find its place *within* the harmony that surrounded it. For medieval Christianity life was oriented by its relation to a unifying creator and the hope for salvation. Though the civilisations of Ancient Greece and medieval Christianity are markedly different, both are organised by an explicit orientation to the world as a meaningful whole.

In contrast, the modern world is concerned only with particulars and the perceived utility of whatever is at hand. In the techno-scientific age, there are myriad and simultaneous instances of projects of utility maximisation. These schemes are deprived of any explicit unifying purpose, despite the fact that these projects are often connected. Thus, our situation within the world as a whole is rendered invisible behind the immediate or short-term opportunity for some sort of material gain.

## Conclusion

In this chapter, my previous observations about the experiment and theory in modern science led me to reflect on Heidegger's thought on the technological thinking that permeates the modern age. Heidegger's reflections on technology highlight another aspect of my central thesis that scientific thinking has significantly changed the modern understanding of the world. By viewing the world technologically, it appears to us as a collection of processes and forces that (because of the assumptions of indirect mathematisation and perfect causality, and the process of experimentation) allows for scientific prediction and control. Therefore, nature can be used for our innumerable projects of material expansion. The techno-scientific perspective encourages a relation to the world in which we believe we have the right to organise and manipulate nature for our own benefit.

I will expand on the connection between science and technology in the following chapter. I will do this by demonstrating the connection between the technological spirit as outlined by Heidegger (and summarised above) and the methodology of modern, mathematical science discussed in the above sections on perfect causality, indirect mathematisation and experimentation. I will also consider certain non-methodological aspects of modern science (such as its role in business, governance, and power relations in these domains), which further demonstrate the link between techno-instrumental thinking and modern science.

# Chapter Four: Modern Mathematical Science as Techno-Science

In this chapter I will further explicate my overall thesis that modern scientific thinking has radically changed the way we think about the world by considering Heidegger's account of the technological spirit of the modern age. I will expand on the presentation of Heidegger's thought on technology in the previous chapter by further elucidating the connections between the technological understanding of the world and modern mathematical science.

The transformation of meaning which is the hallmark of the modern age, as I described it in the previous chapter (that is, the placement of people and things within a universal system of utility maximisation) is perhaps most strikingly evident in the modern scientific thinking I characterised in chapters one and two. Likewise, the technological mode of understanding is also evident in the changing role of science in modernity (for example, in regards to its institutional setting, its relations with business and governance, and the parameters of its research endeavours). In particular, it is evident in the modern expectation that scientific knowledge must be useful and applicable; this is contrary to pre-modern expectations.

However, prior to changes in the function and role of science in modern civilisation, the methodology and metaphysical presuppositions of early modern science (for example, in the physics of Galileo and Newton) also display an inherent link with the technological spirit that Heidegger describes. Before extending the connection between modern scientific methodology (as outlined in chapters one and two) and the technological mode of understanding the world introduced in the previous chapter, I will first consider in a broader manner the connection between Galilean/Newtonian physics and the techno-scientific mode of reasoning. Following this will be a reflection on those non-methodological aspects of modern science (its function in business, governance and power relations) that are imbued with the technological spirit. In turn, this will entail a reflection on the techno-scientific evaluation of knowledge.

As mentioned above, the modern scientific methodology is the most obvious expression of the modern technological understanding of the world. As I have repeatedly stated, modern science investigates nature in such a way that presupposes the mathematical and strictly lawful character of the world. In addition, nature is conceived as something separate from us about which we can establish a body of objective (that is, perspective-independent and disinterested) knowledge. As a consequence of modern science's ability to predict and its focus on particular instances of natural phenomenon, those forces and processes are studied and incorporated into projects of material accumulation and planetary domination. The techno-scientific perspective does not acknowledge our placement within, reliability on and responsibility for the world that is our home. The world as our home and the world as a formal and mathematical construct are vastly different. However, the pervasiveness of techno-scientific thinking threatens to undermine this distinction.

Contrary to the typical explanation, Heidegger contends that modern technology is not simply applied science but instead is the place wherein the initially hidden character of modern science resides.[133] Therefore, in what follows I will attempt to make obvious the connection between modern scientific thinking (as outlined previously) and the essence of technology.

## Modern Mathematical Science and Technological Reasoning

For Heidegger (1978), the ground out of which modern science and technology both grow is the techno-scientific understanding of the world described above; an understanding that investigates and manipulates what it encounters solely in terms of its inner functioning and processes so that these may be channelled in order to yield the object's maximum output.

Similar to Husserl's account of modern science, Heidegger also sees modern physics (i.e., starting from the physics of Galileo and Newton) as the preeminent science that demonstrates the character of the modern age. Following the changes in early modern physics, the natural sciences establish a representational model[134] we use to 'pursue and entrap nature as a calculable coherence of forces'.[135] We 'pursue and entrap nature' in modern science by reducing it, as in the experimental procedure, to particular instances of natural processes that can be described mathematically and

[133] Kisiel 1970, p. 179.
[134] That is, a model based on human thinking that is established prior to encountering actual things and determines the way in which things will be encountered. This aspect of modern science was outlined in chapter two when reflecting upon the modern experiment and the role of theory in modern science.
[135] Heidegger 1978, p. 228.

redeployed in numerous areas of military, residential, commercial and industrial infrastructure and projects. It is precisely as an amalgamation of mathematically definable forces that nature is opened up to a technical project that can manipulate and allocate these forces as the need arises. By starting with the theoretical assumptions outlined in chapters one and two (that is, that nature is written in mathematical language, follows strict causal laws, and can be understood simply by the experimental and measuring procedures that determine the adequacy of hypothetical laws) modern physics investigates nature in such a way that it is seen only as exactly calculable, measurable and orderable precisely because, as outlined previously, it replaces the experiential world with an extensive formal construct. Hence, for Heidegger, the application of technical apparatus based on scientific principles and the ordering of the world at the heart of technology also lurks in the modern scientific methodology and its universal formal system.

Particular objects being investigated are quantified so that they can be situated in the assortment of forces and processes that the universal formal system of modern science describes. As situated within this formal system, the meaning of particular objects is determined by this new way of investigating nature. In this way, science is able to construct 'a new picture of nature from the bottom up, believing that, eventually, human reason will master all that-is'.[136]

## The Institutional Setting of Modern Science

The trend towards scientism or techno-science (as an effective science) was accentuated by changes in the institutional setting of natural science after the First World War.[137] Natural science was no longer pursued solely within the university setting but branched out into innumerable research projects conducted at 'special institutions which were increasingly controlled by commercial interests'.[138] These commercial entities are more interested in procuring scientific advances that are useful and applicable, than those that may improve our understanding.[139] This is because commercial entities operate according to the instrumental reasoning at the heart of the techno-scientific mode of thinking; scientific knowledge is evaluated in

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[136] Učník 2007, p. 307.
[137] *Ibid*., p. 313.
[138] *Ibid*., p. 313.
[139] A similar claim is made by Husserl in 'The Vienna Lecture', *The Crisis of European Sciences and Transcendental Phenomenology*, Evanston: North West University Press, 1970.

terms of its usefulness in extracting the maximum benefit from whatever it works upon. Thus, the pursuit for knowledge and understanding are encroached by market values.[140] As Steve Fuller observes,

> because money is at issue at the outset of research, only research that is likely to succeed (because it fits with a discipline's expectations or it fills a clear niche in the market for new technologies) is likely to be supported [by private sources]. This mentality undercuts the incentive for providing substantial criticism to the fundamental presuppositions of existing research (Fuller 2000, p.12).[141]

Thus, scientific inquiry is increasingly constrained by what Fuller refers to as 'financial censorship'.[142] Under these circumstances, science develops a business or management character in which it merely pursues 'results and their further elaboration and application'.[143]

This kind of effective, commercial techno-science is often encouraged and protected by national governments and international, inter-governmental organisations. For example, the association between science, business and government is patently obvious in the Trade-related Aspects of Intellectual Property Rights (TRIPS) agreement forged during the Uruguay Round (1986-94) of the World Trade Organisation (WTO). Through patents and copyright, a market for technological and scientific knowledge is created by means of its restriction and the conditionality of its exchange. As Robert Hunter Wade has indicated, this has increased the flow of rents from the South (the 'net consumer' of patentable knowledge) to the North (the 'net producer') (2003, p.624).[144] Furthermore, by limiting (essentially outlawing) the ability of developing countries to make use of 'reverse-engineering, imitation, and many strategies of innovation', the TRIPS agreement severely constrains the development aspirations of many developing nations.[145] The control of technological-scientific knowledge that the TRIPS agreement hoped to secure was

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[140] As a result, for example, in the pharmaceutical industry, research and funding are channelled toward 'lifestyle drugs' such as hair-replacement technologies because of the large market for these kinds of products. Therefore, less profitable products such as cures or remedies for diseases widespread in poorer countries, do not receive the same kind of funding or research. See Anna Lanoszka, "The Global Politics of Intellectual Property Rights and Pharmaceutical Drug Policies in Developing Countries", *International Political Science Review*, 2003, Vol. 24, No. 181.

[141] Fuller, Steve, *The Governance of Science: Ideology and the Future of the Open Society*, Buckingham: Open University Press, 2000.

[142] *Ibid*., p. 12.

[143] Kockelmans 1970a, p. 193.

[144] Wade, Robert Hunter, 'What strategies are viable for developing countries today? The World Trade Organization and the shrinking of "development space"', *Review of International Political Economy*, 10:4, November 2003, pp. 621-644.

[145] *Ibid*., p. 626.

supported by the few Northern industries the agreement would benefit most.[146] In this instance we can see techno-science not merely as an effective knowledge directed by commercial interests, but also as a system of political and power relations. This is very different from the science of the Greeks and the Middle Ages, and even of the circumstances in which the likes of Newton and Galileo were constructing their models early in the modern era. Hence, modern science as business is more likely to forget its original project and grounds.

However, returning scientific research to the university may no longer be a viable solution. As an increasing number of commentators have observed (such as Arendt (1961c)[147] and John Ralston Saul (1997)[148]), the university itself has adopted a technical approach to its educative method, producing graduates with applicable skills for specific areas of expertise. Thus, our universities also are part of the spread of techno-science and the modern scientific evaluation of knowledge. Besides, our universities would be unable to host the kind of technological and scientific research being done by large corporations and multinationals because of the exorbitant prices now involved in this kind of research and the technology it requires.

To return to the account modern science I sketched in chapters one and two, the essence of technology as Heidegger describes it is most noticeable in modern mathematical science's methodology. In particular, it is evident in the assumptions of indirect mathematisation and universal causality, as well as in the experimental procedure itself.

## Techno-Science and the Methodology of Modern Science

Firstly, the assumption of universal causality is necessary if modern science is to fulfil its predictive function. If we can predict we can attempt to control and manipulate natural forces and processes. As I mentioned previously, Husserl observes that assuming an infinite causal chain that determines all objects and events 'makes possible hypotheses, inductions, predictions about the unknowns of [the

[146] These include the pharmaceuticals, software/high-tech, and Hollywood/entertainment industries. They are represented mostly by companies from the USA, EU and Japan. See Wade (2003) and Lanoszka (2003).
[147] Arendt, Hannah, 'The Crisis in Education', *Between Past and Future: Eight Essays in Political Thought*, New York: The Viking Press, 1961c, pp. 170-193.
[148] Saul, John Ralston, *The Unconscious Civilisation*, Victoria: Penguin Group Australia, 1997.

world's] present, its past, and its future'.[149] An understanding of natural events that are determined out of a past set of occurrences, each effect becoming a cause for further effects, finds expression in the modern bent for thinking of nature in terms of processes.[150] It is by mastering these processes and chains of cause and effect that modern science becomes an effective knowledge for dominating nature.

Similarly aligned with the spirit of mastery and domination is the assumption of indirect mathematisation, in which it is assumed that for every qualitative datum there can be found a corresponding quantitative determination. The qualitative is imprecise by its very nature. Therefore, as indicated in chapter one, modern science correlates qualitative experience with quantitative figures that can be precisely determined, measured and calculated. As with the case of perfect causality, indirect mathematisation allows us to predict future events because of the precise calculability of the mathematical realm. Likewise, by means of the 'arithmetization of geometry' discussed above, physical nature is reduced to quantifiable figures. Once again, nature is viewed through the lens of an all-encompassing formal structure that renders everything calculable and measureable. What can be calculated and measured opens itself to prediction. That which is predictable becomes (at least somewhat) controllable. Problematically, it is the success of our techno-scientific projects (based on the replacement of 'things, forces, magnetic fields, light, sound, and so forth' for numbers in a formal construct) that sediments the understanding of nature as a precisely knowable (quantifiable) and causally determined storehouse of resources to be made use of as we see fit.[151]

In the modern experimental procedure, as well as the assumption of perfect causality and the process of indirect mathematisation, we can also observe the technological spirit. As indicated previously, modern science reduces nature to an aggregate of forces and processes to be investigated individually and re-connected via mathematical formulae. Nowhere is this more evident than in the experimental procedure. By first isolating, then dissecting natural events and reconnecting them via mathematical processes and laws, the scientist acquires information about nature that exposes the previously concealed potential of the natural phenomenon. For instance, knowing the chemical composition of minerals (such as coal) allows us to

[149] Husserl 1970, p. 31.
[150] Arendt 1961b.
[151] Učník 2007, p. 298.

extract and make use of the energy stored inside of them. Put differently, and in closer accord with Heidegger, we are already thinking techno-scientifically when we describe minerals as storehouses of energy. In more recent history, understanding the gene code of plant, animal, and human life has made all these ‘objects’ increasingly useful. As Heidegger indicates, modern physics is not experimental because it investigates nature with the use of complex tools in controlled settings.[152] Rather, it is because physics ‘as pure theory, sets upon nature to exhibit itself as a coherence of forces calculable in advance’ that it orders its investigations experimentally so that nature may communicate to us its concealed and useful potential.[153] In accord with both modern mathematical science and the technological spirit (which, I have suggested, coincide) nature must be understood as both calculable and ‘orderable as a system of information’.[154]

In contrast to the modern scientific experiment, Greek ‘*epistēmē*’ and medieval ‘*doctrina*’ knew only of ‘*empeiria*’ or ‘*experientia*’.[155] Kockelmans describes this ‘empirical’ element of pre-modern science as

> the observation of things, their properties, and changes under *varying circumstances* and conditions which, provided they are systematically performed, lead to knowledge of the way in which *things as a rule behave*.[156]

Aristotle’s physics is the obvious example of this kind of pre-modern *experientia*; a physics based on experience, not experiment.[157] In contrast, ideal conditions in the modern experiment disclose the scientific assumption that the object being investigated can be mastered both in the experimental setting and in the calculations that precede it. According to Heidegger[158], the *a priori* conception of nature in modern science represents nature as a coherence of forces that can be mathematically mastered and thus rendered useful. Therefore, to repeat what was discussed previously, in viewing the world as a set of forces and minute constituents of matter,

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152 Heidegger 1978a, p. 228.
153 *Ibid.*, p. 228.
154 *Ibid.*, p. 229.
155 Heidegger 1976, p. 345.
156 Kockelmans 1970a, p. 190, italics added.
157 As Heidegger notes, ‘Aristotle fought in his time precisely to make thought, inquiry, and assertion always a *legein homologoumena tois phainomenois*, “saying what corresponds to that which shows itself in beings”’ (Heidegger 1978b, p.195). For example, Aristotle, following our daily experience of the world, observed that light objects rise upwards and heavy objects fall downwards. Therefore, there could be no universal laws for Aristotle as nothing of the sort shows itself to us in our everyday observations.
158 See also Heidegger, Martin, ‘Modern Science, Metaphysics, and Mathematics’ in *Basic Writings*, Ed. David Farrell Krell, London: Routledge, 1978b, pp. 185-212.

as an aggregate of things pieced together, predictable, controllable and manipulable, a relation to the world is encouraged in which we think we have the right to use and exploit those things and forces. Humans, viewed scientifically, escape neither the universal formulation, nor the projects of planetary organisation and utility maximisation.

Moreover, while modern science objectifies nature, it also, simultaneously, deprives the world of its object-character. For Heidegger, object-character relates to meaningful things that we encounter and handle in our everyday world. The world has lost its separate object-ness in a twofold sense. Firstly, the object is only encountered as an instance of determining conditions and causes derived from human reasoning.[159] In order to locate the object within a set of mathematical laws it must be reduced to the reading it provides on particular measuring instruments. Secondly, the object is not encountered as a meaningful particular but only as an instance of forces and processes that allow for prediction and integration into useful projects. As I indicated in chapter two, for modern science the particular table or chair appear only as collections of subatomic particles and universal forces and processes; they are not things in themselves. What is significant for Heidegger is that a perspective that takes matter and forces as its primary focus is no longer concerned with meaningful things as they stand before us. The table I write on is no longer simply the table I use to work on, nor is it recognised as a particular instance of the genus ‘table’. Instead, we now reduce it to a collection of atoms that takes its current form due to the workings of external forces; or, technologically, as an entity significant only to the extent that it can be integrated into a project of utility maximisation. As Heidegger claims, ‘[w]hatever stands by in the sense of standing-reserve no longer stands over against us as object’.[160]

In an age when the object has lost its object-character then the subject (though still considered the ground of knowledge) is also included in the universal scientific explanation. In other words, humans, from a natural scientific perspective, are also (biological) assemblages of matter, governed by inexorable laws and natural forces. Humans therefore find themselves in ‘a continual schizophrenic relation to the world’, in which we are both that living being which (according to modern science)

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[159] See Heidegger ‘Lecture Five’, *The Principle of Reason*, Indiana: Indiana University Press, 1996 (1955).
[160] Heidegger 1978a, p. 225.

can build an objective, disinterested body of knowledge based on precise facts and causal laws, but also a natural instance of chemical, biological and physical forces and processes like any other object of the natural sciences.[161] This understanding allows for the inclusion of humans in the 'resource pool'. In order to consider ourselves from a natural scientific perspective our understanding of knowledge, truth, and their relation to the world had to alter significantly.

Aron Gurwitsch maintains that there is a connection between the new understanding of truth and the understanding of humans as vital organisms that can be exhaustively explained in natural scientific language.[162] By considering ourselves primarily as vital beings, an approach is adopted in which our opinions (which have replaced any transcendental notion of truth) are considered in terms of their causes and effects.[163] Opinions (truths) are then evaluated in terms of their functional value. Nothing is true until it has proven its worth and ability in bringing 'about satisfactory results'.[164] Similarly, Kisiel observes that scientific categories are now working hypotheses 'whose "truth" is measured in terms of the efficiency with which they perform their task'.[165] Consequently, the notion of truth itself has changed and is now measured in accord with the applicability of the facts it reveals case by case. As Husserl would contend, by reducing truth to mental states and useful opinions, we usher in a propensity toward relativism and scepticism and the ancient distinction between *episteme* and *doxa* collapses.

Thus, formal, scientific knowledge is pursued and constructed with the intention of rendering our surrounding world more useful.[166] Patočka summarises the new modern attitude towards knowledge, as articulated by Francis Bacon:

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[161] Učník 2007, p. 299.
[162] Gurwitsch 1945, p. 173.
[163] *Ibid*., p. 173.
[164] *Ibid*., p. 186.
[165] Kisiel 1970, p. 182.
[166] The *Ecole Polytechnique* of the early- to mid-nineteenth century was influential in the spread of French positivism (through the thought of Henri de Saint-Simon and Auguste Comte) and also noteworthy for its emphasis on the practical nature of knowledge. Thus, the natural sciences and mathematics were taught with their eventual applicability in mind, particularly for military and engineering purposes. Hence, the *Polytechnique* was a precedent for those institutions of the twentieth century that would introduce in an organised and abundant manner the kind of 'technical specialist' that has been central to the political, commercial and military activities of recent history. See Hayek (1941). For a full account of the positivist evaluation of knowledge in terms of its usefulness, see Kolakowski, Leszek, *Positivist Philosophy: From Hume to the Vienna Circle*, Middlesex and Victoria: Penguin Books Ltd, 1972.

> [K]nowledge is power, only effectual knowledge is real knowledge, what used to apply only to practice and production now holds for knowledge as such; knowledge is to lead us back to paradise, the paradise of inventions and possibilities of transforming and mastering the world to suit our needs while those needs remain undefined and unlimited… (Patočka 1996, p.84).[167]

In other words, '[i]n the ever accelerating race to manipulate nature, now understood as a resource for humans, knowledge becomes an efficient instrument used to discover more and more "facts" in order to utilise them'.[168] With this new attitude towards the world centring around the 'usefulness' of nature and knowledge, the division between science and technology collapses in order that they both may be enhanced to assist our mastering projects based on calculation, prediction, interference and applicability.

## The Danger of the Essence of Technology

Once we describe natural events mathematically and separate them into constituent parts and processes, they become easier to predict. Therefore, when we are thinking techno-scientifically (that is, evaluating nature and knowledge in terms of their usefulness), we consider predictable natural events only to the extent that they can be integrated into our innumerable projects of material gain and expansion. As outlined above, this techno-scientific way of thinking is the dominant way in which we understand the world in the modern period.

Heidegger is troubled by the prospect that we are living in an age in which the kind of understanding that holds sway in the techno-scientific age – a mass controlling and ordering of the world that we consider an abundant resource – has become the only way in which the world is understood by us and that we tend to derive 'all [our] standards on this basis'.[169] In other words, we relate to the world and ourselves in a way consistent with the ordering and securing of the techno-scientific project at the expense of all other kinds of relating or possibilities of understanding ourselves and the world.

At the level of governance and societal organisation, politics, economics and law will regulate human interactions and science will work upon nature to secure the

[167] Patočka, Jan, *Heretical Essays in the Philosophy of History*, Illinois: Open Court Publishing Company, 1996.
[168] Učník 2007, p. 308.
[169] Heidegger 1978a, p. 231.

continual expansion of our civilisation. In our everyday lives, we will 'consume' art and literature in order to 'improve' ourselves; we will maintain human bonds for the sake of the smooth running of society, the benefits of networking, and to maintain our spiritual sturdiness; we will walk through our parks in order to preserve our health. When the technological mode of revealing is dominant, everything becomes a means for some end. Or, as Gurwitsch contends, everything is done in order to satisfy some vital need or desire.[170]

Simultaneously (and what at first seems contradictory), particular optimising projects become the guiding concern of a seemingly autonomous system of dispersed though often connected opportunities of optimisation. In other words, the principle that guides our actions and lives is no longer based on any grand theological, philosophical or revolutionary ideal: our guiding principle is based on the notion of usefulness and extracting the maximum yield from whatever opportunities are presented to us. Our focus on higher order questions of meaning and governing principles is lost in a sea of particular concerns. Put differently, life's meaning becomes identical with the optimising project itself. Indeed, science can describe humans techno-scientifically only when 'meaningful distinctions and hierarchical value systems' have been removed (Belu and Greenberg 2010, p.2).[171] When Heidegger maintains that the world is considered a resource for our projects he is *not* suggesting that we make some explicit acknowledgement of the world as a whole. This way of viewing things in regards to their usefulness is related to *particular* objects and processes; *there is no view of the world as a whole*. The world is encountered as an extensive resource pool not in its entirety but only as a collection of myriad opportunities of utility maximisation (similar to the way modern science considers the world an aggregate of individual forces and processes).

## Conclusion

In this chapter I have considered the connection between Heidegger's thought on the technological understanding of the world and modern science. This included a reflection on the institutional setting of modern science and its role in business, governance and power relations. Connecting back with chapters one and two, I

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[170] Gurwitsch 1945, p. 38.
[171] Belu, Dana S., and Andrew Freenberg, 'Heidegger's Aporetic Ontology of Technology', *Inquiry*, Vol. 53, No. 1, pp. 1-19.

suggested a link between technological thinking and the modern scientific methodology of perfect causality, indirect mathematisation and experimentation.

As I have argued throughout this chapter, the world reveals itself to techno-scientific reasoning, but only as a world to be calculated and ordered, and only as a world of *res extensa* and the forces that are the object of techno-science. 'Any other possibility of uncovering things is *a priori* discredited as unscientific, therefore untrue'.[172] The nature of truth has therefore changed and must now, as in the case of the experiment, conform to the usefulness and applicability of the latest scientific findings. As indicated above, the meaning of nature, ourselves, and the world has also changed. All things are now incorporated and appropriately placed in an optimising-system in accord with their instrumentality. Other ways of reasoning about the world that are incompatible with scientific formulations and instrumental thinking are overlooked. Thus, as Patočka suggests, the modern spirit of technology within which we reside suppresses that within us 'which is responsible for meaning, for clarity and truth'.[173] Meaning, clarity, truth, responsibility and morality fall outside the scope of formal knowledge and mathematical language. Thus, in an age dominated by techno-scientific reasoning, these other modes of thinking and understanding are neglected.

[172] Učník 2007, p. 312.
[173] Patočka 1976, p. 329.

# Conclusion

As I have argued throughout this dissertation, modern mathematical science shapes our modern understanding of the world. This understanding would have been alien to the Ancient Greeks and the medieval people, both of whom had a conception of the world radically different from the modern scientific outlook. The modern scientific understanding is based on metaphysical assumptions that I have outlined in my dissertation. As a result, the metaphysical assumptions constitute the ground of modern science and illustrate the radically different way we see the world.[174]

As outlined in the first chapter, these assumptions include the ideas of perfect causality and indirect mathematisation, as well as the idea of a geometric world that can be described by mathematical language. In order to describe nature mathematically and think of ideal, geometric shapes as constituting the material world, early modern scientists collapsed the two Platonic realms (one of ideal, unchanging being, the other of the everyday world of becoming) into an extensive formal manifold.

In the second chapter I discussed another key feature central to the modern scientific methodology; namely, the process of experimentation in which particular events and processes are isolated and investigated under ideal conditions in accord with the theoretical framework and the assumptions of modern science.

Significantly, the mathematical description of nature and the measurements and observations made with the assistance of sophisticated technical machinery are now considered as the world itself. Science supposedly uncovers the underlying reality of things that we cannot experience in the world of our living.

Following Heidegger, in chapter three, I argued a better understanding of modern science can be gained by reflecting upon the broader modern techno-scientific conception of the world. When we think about the world in techno-scientific terms, we view nature as a collection of forces and processes which we believe we have the right to organise and manipulate for our own advantage. Although such a project is supposedly for the benefit of human beings, humans do not escape the universal

[174] Exponents of modern science (and philosophy) often claim that their thinking is free of metaphysics.

evaluation of scientifically describable objects and processes that can be ordered and used in projects of economic, political and social organisation. Humans are objects alongside other natural objects that are subject to mathematical laws and natural processes. Consider, for example, the tendency to explain all aspects of human life in terms of evolutionary theory. This description assumes that an observing scientist somehow finds a disinterested position outside of the process that he/she describes. The techno-scientific project, in which we evaluate all worldly things in terms of their expediency, includes our surrounding world, the particular objects we encounter, and the lives of human beings.

Finally, in the fourth chapter, I developed and further elaborated the description of modern science and the techno-scientific understanding of the world. I sketched the institutional setting of science and its relationship with business, governance, and power relations in these domains. I noted a closer link between the methodological aspects of modern science, which include the assumptions of indirect mathematisation and perfect causality, and the process of experimentation. These assumptions are grounded in the techno-scientific understanding of the world where particular objects and processes are located within a broader scheme of utility maximisation. This techno-scientific mode of thinking dominates the way in which we understand the world in the current age. Those modes of understanding, thinking and reasoning that do not adhere to the fundamental conceptions of modern science are rejected as illusory.

In conclusion, I want to suggest that we can attempt to question the techno-scientific understanding of the world by reflecting on the world we inherit from tradition in the way Patočka proposes in *Heretical Essays in the Philosophy of History.*[175] In our case, this tradition is comprised of techno-scientific categories. This reflection upon techno-scientific reasoning includes a mode of questioning and an attitude of responsibility towards a meaning that is always under threat, rather than simply accepting the scientific ideas as they come to us. However, this is not an easy task. It requires an explicit acknowledgement of the way past epochs have understood the world and a recognition of our historical situation as informed and shaped by our relation to these past epochs.

[175] Patočka, Jan, *Heretical Essays in the Philosophy of History*, Illinois: Open Court Publishing Company, 1996.

Perhaps in taking up this questioning and seeking of meaning we will not simply investigate and make use of the world as if it were a large resource to be allocated to projects of expansion and material conquest. Instead, we may foster an attitude in which we recognise the world as the home for which we are responsible.

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