(Draft. Please treat accordingly. Translated by Phlippa Shimrat, and [not yet completely] edited by Peter McLaughlin and Gideon Freudenthal)

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The Social and Economic Roots of Newton's *Principia*[1]

Introduction: Formulation of the Problem[2] [Marx's Theory Of The Historical Process]

Both the work and the personality of Newton have attracted the attention of scientists of all nations and in all periods. The vast range of his scientific discoveries, the significance of his work to all subsequent developments in physics and technology, and the remarkable accuracy of his laws justifiably arouse special respect for his genius.

What placed Newton at the turning point of the development of science and enabled him to chart new paths forward?

Where is the source of Newton's creative genius? What determined the content and the direction of his work?

These are the questions that inevitably confront the researcher who aims not merely to gather materials relating to Newton but to penetrate into the very essence of his creative work. As Pope said in a well-known couplet:

> "Nature and nature's laws lay hid in night;
> God said 'Let Newton be!' and all was light."

Our new culture, stated the famous British mathematician Professor Whitehead in his recent book *Science and Civilization,* owes its development to the fact that Newton was born in the same year that Galileo died. Just think what the course of human history would have been if these two men had not appeared in the world.[3]

The well-known English historian of science F. S. Marvin, a member of the presidium of this International Congress, concurred with this view in his article: "The Significance of the 17th Century," which appeared a couple of months ago in *Nature.*[4]

Thus the phenomenon of Newton is attributed to the benevolence of divine providence, and the mighty impetus that his work gave to the development of science and technology is attributed to his personal genius.

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[1] The Russian Title: "The Socio-Economic Roots of Newton's Mechanics."

The original English version had the footnote on the first page: "The quotations cited in this essay have been translated from Russian. The chief exceptions are the quotations from *Nature* in Chapter 5."

[2] The original English version had the section title "Marx's theory of the historical process".

[3] Whitehead's original reads: "Our modern civilization is due to the fact that in the year when Galileo died, Newton was born. Think for a moment of the possible course of history supposing that the life's work of these two men were absent." A.N. Whitehead, "The First Physical Synthesis" in *Science and Civilization*, ed. F.S. Marvin (Oxford Univ. Press, 1929). The Whitehead passage is quoted by F.S. Marvin in the essay cited below in footnote 5.

[4] F.S. Marvin, "The Significance of the 17th Century," which is a (laudatory) book review of G.N. Clarke's *The Seventeenth Century* (Oxford: Oxford Univ. Press, 1929). Marvin was the senior figure among the organizers of the London Congress; Clarke was the opening speaker of the first session of the Congress.

In this paper we shall present a radically different view of Newton and his work.

We aim here to apply the method of dialectical materialism and Marx's conception of the historical process to an analysis of the genesis and development of Newton's work within the context of the period in which he lived and worked.

We shall give a brief exposition of Marx's basic assumptions that will be the guiding premises of our paper.

Marx expounded his theory of the historical process in the preface to the *Critique of Political Economy* and in the *German Ideology*. We shall attempt to convey the essence of Marx's views as far as possible in his own words.

Society exists and develops as an organic whole. In order to ensure its existence and development society must develop production.[5] In the social production of their life men enter into definite relations that are independent of their will. These relations correspond to a definite stage of development of their material productive forces.

The sum total of these relations of production constitutes the economic structure of society, the real foundation, on which rises a legal and political superstructure and to which correspond definite forms of social consciousness.

The mode of production of material life conditions the social, political and intellectual life process of society.

It is not the consciousness of men that determines their being, but, on the contrary their social being determines their consciousness. At a certain stage of their development the material productive forces of society come into conflict with the existing relations of production, or—what is but a legal expression for the same thing—with the property relations within which they have been at work hitherto.

From forms of development of the productive forces, these relations turn into their fetters. Then begins an age of social revolution. With the change of the economic foundation the entire immense superstructure is also transformed.

The prevailing consciousness during these periods must be explained by the contradictions of material life, by the existing conflict between the productive forces and the relations of production.

Lenin remarked that this materialist conception of history removed the two chief shortcomings in earlier historical theories.

Earlier historical theories examined only the *ideological* motives in the historical activities of human beings. Consequently, they were unable to reveal the true origins of those motives and regarded history as being driven by the ideological impulses of individual human beings, thereby blocking the way to recognition of the objective laws of the historical process. "Opinion governed the world." The course of history depended on the talents and the personal impulses of man. The individual created history.

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[5]The following paragraphs contain an almost verbatim paraphrase of Lenin's remarks on the materialist conception of history in "Karl Marx" (1918) in *Collected Works 21*, 43-91 (see pp. 55-57), which in turns extensively quotes Marx from the Preface to the *Contribution to the Critique of Political Economy* (MEW 13, 9; LW 21, 55–57).

Professor Whitehead's above-quoted view of Newton is a typical example of this limited understanding of the historical process.

The second shortcoming that Marx's theory removes is the view that the subject of history is not the mass of the people, but individuals of genius. The most obvious representative of this view is Carlyle, for whom history was the story of great men.

According to Carlyle, the achievements of history are only the realisation of the thoughts of great men. The genius of the heroes is not the product of material conditions, but on the contrary the creative power of genius transforms those conditions, since it has no need for any external material factors.

In contradistinction to this view Marx examined *the movement of the masses* who make history and studied the social conditions of the life of the masses and the changes in those conditions.

Marxism, as Lenin emphasised, pointed the way to an all-embracing and comprehensive study of the process of the rise, development and decline of social systems. It explains this process by examining the totality of opposing tendencies, by reducing them to the precisely definable conditions of life and production of the various classes.[6]

Marxism eliminates subjectivism and arbitrariness in the selection of the various "dominant" ideas or in their interpretation, revealing that, without exception, all ideas stem from the condition of the material productive forces.

In class society the ruling class subjects the productive forces to itself and, by virtue of its being the dominant material force, subjects all other classes to its interests.[7]

The ideas of the ruling class are, in every historical age, the ruling ideas, and the ruling class distinguishes its ideas from all previous ideas by presenting them as eternal truths. It wishes to reign eternally and bases the inviolability of its rule on the eternal nature of its ideas.

In a class society the dominant ideas are separated from the relations of production, thus creating the notion that the material basis is determined by ideas.

Practice should not be explained by ideas, but on the contrary, ideological structures should be explained by material practice.

Only the proletariat, which aims to create a classless society, is free from a limited understanding of the historical process and produces a true, genuine history of nature and society.

The period during which Newton was at the peak of his activity coincided with the period of the English Civil War and Commonwealth.

A Marxist analysis of Newton's activity on the basis of the foregoing assumptions will consist first and foremost in understanding Newton, his work and his world outlook as a product of that period.

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[6] This and the next paragraph: LW 21, 57

[7] See German Ideology MEW 3, 46–48 CW 5, 59–60

The Economics, Technology and Physics of Newton's Era[8]

The segment of world history that has come to be known as medieval and modern history was first and foremost characterized by the rule of private property.

All the social and economic formations of this period feature this basic characteristic.

Consequently Marx regarded this period of human history as the history of the development of forms of private property, and distinguished three subsidiary periods within the larger era.

The first period is that of feudalism. The second period begins with the disintegration of the feudal system and is characterised by the emergence and development of merchant capital and manufacture.

The third period in the history of the development of private property is that of industrial capitalism. It gave birth to large-scale industry, the harnessing of the forces of nature to the goals of industry, mechanisation and the most detailed division of labour.

The dazzling flowering of natural science during the 16th and 17th centuries resulted from the disintegration of the feudal economy, the development of merchant capital, of international maritime relations and of heavy (mining and metallurgical) industry.

During the first centuries of the mediaeval economy, not only the feudal but also to a considerable extent the urban economy were based upon personal consumption.

Production for the purpose of exchange was only beginning to emerge. Hence the limited nature of exchange and of the market, the insular and stagnant nature of the forms of production, the isolation of the various localities from the outside world, the purely local connections among producers: the feudal estates and the commune in the country, the guild in the towns.

In the towns, capital was in kind, directly bound up with the labour of the owner and inseparable from him. This was corporation capital.[9]

In the mediaeval towns there was no strict division of labour among the various guilds, nor within those crafts among the individual workers.

The lack of intercourse, the sparse population and the limited extent of consumption hindered any further growth in the division of labour.

The next step in the division of labour was the separation of production from the form of exchange and the emergence of a special merchant class.

The boundaries of commerce were widened. Towns formed relations with each other. There arose a need for publicly safe roads, and a demand for good means of communication and transport.

The emerging links between towns led to the division of production among them. Each developed a special branch of production.

Thus the disintegration of the feudal economy led to the second period in the history of the development of private property, to the rule of merchant capital and manufacture.

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[8] The original English version has a different order in the title: Economics, Physics and Technology.

[9] "ständisches Kapital": This page summarizes part of the Section on Feuerbach of the German Ideology: MEW 3 51-56 CW 4, 66–69

The emergence of manufacture was the immediate consequence of the division of labour among the various towns.

Manufacture led to a change in relations between the worker and the employer. A monetary relation emerged between the capitalist and the worker.

Finally, the patriarchal relations between master and journeymen were destroyed.

Trade and manufacture created the haute bourgeoisie. The petty bourgeoisie were concentrated in guilds and, in the towns, were compelled to submit to the hegemony of the merchants and the manufacturers.

This period began in the mid-17th century and continued to the end of the 18th.

This is a schematic outline of the course of development from feudalism to merchant capital and manufacture.

Newton's activities fall within the second period in the history of the development of private property.

Consequently, we shall first investigate the historical demands presented by the emergence and development of merchant capital.

Then we shall consider what technical problems were posed by the newly developing economy and what complex of physical problems and knowledge, essential for solving these technical problems, they generated.

We shall focus on three prominent spheres that were of decisive importance to the social and economic system we are investigating: communications, industry and war.

Communications

Trade had already reached a considerable level of development by the beginning of the Middle Ages. Nevertheless, land communications were in a very poor state. Roads were so narrow that not even two horses could pass. The ideal road was one on which three horses could travel side by side, where, in the expression of the time (the 14th century) "A bride could ride by without touching the funeral cart."

It is no wonder that goods were carried in packs. Road construction was almost non-existent. The insular nature of the feudal economy gave no impetus whatever to developing road construction. On the contrary, both the feudal barons and the inhabitants of places through which commercial transport passed were interested in maintaining the poor condition of the roads, because they had the Grundrührrecht[10], the right of ownership to anything that fell on to their land from the cart or pack.

The speed of land transport in the 14th century did not exceed five to seven miles a day.

Naturally, maritime and water transport played a large role, both because of the greater load-capacity of ships and also because of their greater speed: the largest two-wheeled carts drawn by ten to twelve oxen hardly carried two tons of goods, whereas an average-sized ship could carry up to 600 tons. During the 14th century the journey from Constantinople to Venice took three times as long by land as by sea.

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[10] Literally "Ground-touching-right".

Nevertheless even the maritime transport of this period was very inadequate: as reliable methods of establishing a ship's position in the open sea had not yet been invented, they sailed close to the shores, which made their journey much slower.

Although the mariner's compass was first mentioned in the Arab book, *The Merchant's Treasury,* in 1242, it did not come into universal use until the second half of the 16th century. Geographical maritime maps made their appearance at about the same time.

But compass and charts can be rationally utilized only when the ship's position can be correctly established, i.e., when latitude and longitude can be determined.

The development of merchant capital destroyed the isolation of the medieval town and the village commune, immensely extended the geographical horizon, and considerably accelerated the pace of life. It needed comfortable means of transport, improved means of communication, a more accurate measurement of time, especially in light of the ever accelerating pace of exchange, and precise tools of calculation and measurement.

Particular attention was directed to water transport: to maritime transport as a link between various countries, and to river transport as an internal link.

The development of river transport was also assisted by the fact that since antiquity waterways had been the most convenient and most investigated means of communications, and the natural growth of the towns was connected to the system of river communications. River transport was three times as cheap as haulage transport.

The construction of canals also developed as an additional means of internal transport and as a means of connecting maritime transport with the internal river system.

Thus the development of merchant capital confronted water transport with the following technical problems:

In the realm of water transport.

1. Increasing the tonnage capacity of vessels and their speed.

2. Improving the vessels' buoyancy: increased stability, sea-worthiness, a reduced tendency to rock, greater navigability and ease of manoeuvring, which was especially important for war-vessels.

3. Convenient and reliable means of determining position at sea: means of determining latitude and longitude, magnetic deviation, times of tides.

4. Improving internal waterways and linking them to the sea; building canals and locks.

Let us consider what physical premises are necessary in order to solve these technical problems.

1. In order to increase the tonnage capacity of vessels it is necessary to know the fundamental laws governing bodies floating in fluids, since in order to estimate tonnage capacity it is necessary to know the method of estimating a vessel's water displacement. These are problems of hydrostatics.

2. In order to improve the buoyancy of a vessel it is necessary to know the laws governing the motion of bodies in fluids, which is an aspect of the laws governing the motion of bodies in a resistant medium—one of the basic problems of hydrodynamics.

The problem of a vessel's stability when rocking is one of the basic problems of the mechanics of material points [the system of points].

3. The problem of determining latitude consists in the observation of heavenly bodies, and its solution depends on the existence of optical instruments and a knowledge of the chart of the heavenly bodies and their motion—of celestial mechanics.

The problem of determining longitude can be most conveniently and simply solved with the aid of a chronometer. But as the chronometer was invented only in the 1730s, after the work of Huygens, longitude was determined by measuring the distance between the moon and the fixed stars.

This method, proposed in 1498 by Amerigo Vespucci, demands precise knowledge of the anomalies in the motion of the moon and constitutes one of the most complex problems of celestial mechanics. Determining the times of the tides according to locality and the position of the moon demands a knowledge of the theory of gravitation, which is also a problem of mechanics.

The importance of this problem is evident from the fact that in 1590, long before Newton gave the world his general theory of tides on the basis of the theory of gravity, Stevin drew up tables showing the time of the tides in any given place according to the position of the moon.

4. The construction of canals and locks demands a knowledge of the basic laws of hydrostatics, the laws governing the efflux of fluids, since it is necessary to calculate water pressure and the speed of its efflux. In 1598 Stevin, while studying the problem of water pressure, had already discovered that water could exert pressure on the bottom of a vessel greater than its weight; in 1642 Castelli published a special treatise on the flow of water in various sections of canals. In 1646 Torricelli was working on the theory of the efflux of fluids.

As we see, the problems of canal and lock construction also bring us to problems of mechanics (hydrostatics and hydrodynamics).

Industry

By the end of the Middle Ages (14th and 15th centuries) the mining industry was already developing into a large-scale industry. The mining of gold and silver in connection with the development of currency was stimulated by the growth of exchange. While the discovery of America was chiefly

driven by the hunger for gold—since European industry, which had developed so vigorously during the 14th and 15th centuries, and the commerce it engendered, increased the demand for means of exchange—the demand for gold also drew particular attention to the exploitation of mines and other sources of gold and silver.

The vigorous development of the war industry, which had made enormous advances since the invention of firearms and the introduction of heavy artillery, was a powerful stimulus to the mining of iron and copper. By 1350 firearms had become the customary weapon of the armies of eastern, southern and central Europe.

In the 15th century heavy artillery had reached a fairly high level of development. In the 16th and 17th centuries the war industry made enormous demands upon the metallurgical industry.

In the months of March and April 1652 alone, Cromwell required 335 cannon, and in December a further 1,500 guns of a total weight of 2,230 tons, with 117,000 shells as well as 5,000 hand bombs.

It is therefore clear why the problem of how to exploit mines in the most effective way became a matter of prime importance.

The main problem is posed by the depth of the mines. The deeper the mines, the more difficult and dangerous it becomes to work in them.

A variety of devices are necessary for pumping out water, ventilating the mines, and raising the ore to the surface. It is also necessary to know how to construct mines correctly and find one's bearings in them.

By the beginning of the 16th century mining had already reached a considerable level of development. Agricola left a detailed encyclopaedia of mining which shows how much technical equipment had come to be used in mining.

In order to extract the ore and water, pumps and hoists (windlasses and horizontal worms were constructed; the energy of animals, the wind and falling water were all utilized. Ventilation pipes and blast-engines were constructed. There was an entire system of pumps, since as the mines became deeper, water drainage became one of the most important technical problems.

In his book Agricola describes three kinds of water-drainage devices, seven kinds of pumps, and six kinds of installations for extracting water by means of a ladeling or bucketing device, altogether around sixteen kinds of water-drainage machines.

The development of mining demanded vast equipment for processing the ore. Here we encounter smelting furnaces, stamping mills, and machinery for separating metals.

By the 16th century the mining industry had become a complex organism whose organization and management required considerable knowledge. Consequently the mining industry immediately developed as a large-scale industry, free of the guild system, and hence not subject to the stagnation of the guilds. It was technically the most progressive industry and engendered the most revolutionary elements of the working class during the Middle Ages, i.e., the miners.

The construction of galleries demands considerable knowledge of geometry and trigonometry. By the 15th century scientific engineers were working in the mines.

Thus the development of exchange and of the war industry confronted the mining industry with the following technical problems:

1. The raising of ore from considerable depths.

2. Ventilation equipment in the mines.

3. Pumping water from the mines and drainage devices—the problem of the pump.

4. The transition from the crude, damp-blast method of production predominant until the 15th century to blast-furnace production, which, like ventilation, poses the problem of air-blast equipment.

5. Ventilation by means of air draught and special blast-engines.

6. The processing of the ores with the aid of rolling and cutting machinery.

Let us consider the physical problems underlying these technical tasks.

1. The raising of ore and the problem of constructing hoists is a matter of designing windlasses and blocks, i.e., a variety of so-called simple mechanical machines.

2. Ventilation equipment demands a study of draughts, i.e., it is a matter of aerostatics, which in turn is part of the problem of statics.

3. The pumping of water from the mines and the construction of pumps, especially piston pumps, requires considerable research in the field of hydro- and aerostatics.

Consequently Torricelli, Guericke and Pascal studied the problems of raising liquids in tubes and of atmospheric pressure.

4. The transition to blast-furnace production immediately gave rise to the phenomenon of large blast-furnaces with auxiliary buildings, water-wheels, bellows, rolling machines and heavy hammers.

These problems—the problem of hydrostatics and dynamics posed by the construction of water-wheels, the problem of air-bellows—like the problem of blast-engines for ventilation purposes, also require an investigation of the motion of air and air compression.

5. As in the case of other equipment, the construction of presses and heavy hammers driven by the power of falling water (or animals) requires a complex design of cogwheels and a transmission mechanism, which is also essentially a problem of mechanics. The science of friction and the mathematical arrangement of cogged transmission wheels developed in the mill.

Thus, if we disregard the great demands that the mining and metallurgical industries of this period made on chemistry, all these physical problems did not go beyond the bounds of mechanics.

War and War Industry

The history of war, Marx wrote to Engels in 1857,[11] demonstrates ever more graphically the correctness of our views on the connection between the productive forces and social relations.

Altogether the army is very important to economic development. It was in warfare that the guild system of corporations of artisans first originated. Here too was the first use of machinery on a large scale.

Even the special value of metals and their use as money at the beginning of the development of monetary circulation would seem to have been based on their significance in war.

Similarly, the division of labour within various branches of industry was first put into practice in the army. This, in condensed form, is the entire history of the bourgeois system.

From the time that gunpowder (which had been in use in China even before our era) became known in Europe, there was a rapid growth in firearms.

Heavy artillery first appeared in 1280, during the siege of Cordova by the Arabs. In the 14th century firearms passed from the Arabs to the Spaniards. In 1308 Ferdinand IV took Gibraltar with the aid of cannon.

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[11] These four paragraphs paraphrase the third paragraph of a letter of Marx to Engels (25 Sept. 1857, MEW 29, 192; CW 40, 186):

Artillery spread from the Spaniards to other nations. By the mid-14th century firearms were in use in all countries of eastern, southern and central Europe.

The first heavy guns were extremely unwieldy and could only be transported in sections. Even weapons of small calibre were very heavy, since no ratios had been established between the weight of the weapon and the projectile or between the weight of the projectile and the charge.

Nevertheless firearms were used not only in sieges, but also on war-vessels. In 1386 the English captured two war-vessels armed with cannon.

A considerable improvement in artillery took place during the 15th century. Stone balls were replaced by iron. Cannon were cast entirely from iron and bronze. Gun carriages and transportation were improved. The rate of fire was increased. The success of Charles VIII in Italy can be attributed precisely to this factor.

In the battle of Fornova the French fired more shots in one hour than the Italians fired in a day.

Machiavelli wrote his *Art of War* specially in order to demonstrate ways of resisting the effects of artillery by the skillful disposition of infantry and cavalry.

But of course the Italians were not satisfied with this alone, and they developed their own war industry. By Galileo's time the Arsenal at Venice[12] had attained a considerable level of development.

Francis I formed artillery into a separate unit and his artillery shattered the hitherto undefeated Swiss lancers.

The first theoretical works on ballistics and artillery date from the 16th century. In 1537 Tartaglia endeavoured to determine the trajectory of the flight of a projectile and established that the angle of 45 degrees allows the maximum flight distance. He also drew up firing tables for directing aim.

Vannoccio Biringuccio studied the process of casting and in 1540 he introduced considerable improvements in the production of weapons.

Hartmann invented a scale of calibres, by means of which each section of the gun could be measured in relation to the aperture, which set a specific standard in the manufacture of guns and paved the way to the introduction of firmly established theoretical principles and empirical rulesof firing.

In 1690 the first artillery school was opened in France.

In 1697 Saint-Rémy published the first complete artillery primer.

By the end of the 17th century artillery in all countries had lost its mediaeval, guild character and was included as a component part of the army.

The variety of calibres and models, the unreliability of empirical rules of firing, and the almost total lack of firmly established ballistic principles had already become absolutely intolerable by the mid-17th century.

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[12] The original English version contains the mistranslation "Florence".

Consequently, many experiments began to be carried out on the correlation between calibre and charge, the relation between calibre and the weight and length of barrel and the phenomenon of recoil.

The science of ballistics advanced in tandem with the work of the most prominent physicists.

Galileo gave the world the theory of the parabolic trajectory of a projectile; Torricelli, Newton, Bernoulli and Euler studied the flight of a projectile through the air, air resistance and the causes of deviation of the projectile.

The development of artillery led in turn to a revolution in the construction of fortifications and fortresses, and this made enormous demands on the art of engineering.

The new form of fortifications (earthworks, fortresses) almost paralysed the effects of artillery in the mid-17th century, which in turn gave a powerful stimulus to its further development.

The development of the art of war posed the following technical problems:

Intrinsic ballistics.

1. Study and improvement of the processes occurring in a firearm when fired.
2. The stability of the firearm combined with minimum weight.
3. A device for comfortable and accurate aim.

Extrinsic ballistics.

4. The trajectory of a projectile through a vacuum.
5. The trajectory of a projectile through the air.
6. The dependence of air resistance upon the speed of the projectile.
7. The deviation of a projectile from its trajectory.

The physical bases of these problems are as follows:

1. In order to study the processes occurring in the firearm, it is necessary to study the compression and expansion of gases—which is basically a problem of mechanics—as well as the phenomena of recoil (the law of action and reaction).

2. The stability of a firearm poses the problem of studying the resistance of materials and testing their durability. This problem, which also has great importance for the art of construction, was resolved at this particular stage of development by purely mechanical means. Galileo devoted considerable attention to the problem in his *Mathematical Demonstrations*.

3. The problem of a projectile's trajectory through a vacuum consists in resolving the problem of the action of the force of gravity upon the free fall of a body and the superposition of its forward motion with its free fall. It is therefore not surprising that Galileo devoted much attention to the problem of the free fall of bodies. The extent to which his work was connected with the interests of artillery and ballistics can be judged if only from the fact that he began his *Mathematical Demonstrations* with an address to the Venetians praising the activity of the arsenal at Venice and pointing out that the work of that arsenal provided a wealth of material for scientific study.

4. The flight of a projectile through the air is one aspect of the problem of the motion of bodies through a resistant medium and of the dependence of that resistance upon the speed of motion.

5. The deviation of the projectile from the estimated trajectory can be caused by a change in its initial speed, a change in the density of the atmosphere, or by the influence of the rotation of the earth. All these are purely mechanical problems.

6. Accurate tables governing aim can be drawn up provided the problem of extrinsic ballistics is resolved and the general theory of a projectile's trajectory through a resistant medium is established.

Hence, if we exclude the actual process of producing the firearm and the projectile, which is a problem of metallurgy, the chief problems posed by the artillery of this period were problems of mechanics.

The Physical Themes of the Era and the Contents of the *Principia*[13]

Now let us systematically consider the physical problems presented by the development of transport, industry and mining.

First and foremost we should note that they are all *purely mechanical problems*.

We shall analyse, albeit in very general terms, the basic themes of research in physics during the period in which merchant capital was becoming the predominant economic force and manufacture was emerging, i.e., the period from the beginning of the 16th to the second half of the 17th century.

We do not include Newton's works on physics, since they will be analysed separately. By presenting the main physical topics, we will be able to determine the problems that most interested physics in the period immediately preceding Newton and contemporary with him.

1. *The problem of simple machines, inclined planes and general problems of statics* were studied by: Leonardo da Vinci (end of 15th century); Cardano (mid-16th century); Guidobaldo (1577); Stevin (1587); Galileo (1589–1609).

2. *The free fall of bodies and the trajectory of a projectile* were studied by: Tartaglia (1530s); Benedetti (1587); Piccolomini (1597); Galileo (1589–1609); Riccioli (1651); Gassendi (1649); Accademia del Cimento.

3. *The laws of hydro- and aerostatics, and atmospheric pressure. The pump, the motion of bodies through a resistant medium*: Stevin, the engineer and inspector of the land and water installations of Holland (at the end of the 16th and beginning of the 17th centuries); Galileo, Torricelli (first quarter of the 17th century); Pascal (1647–1653); Guericke, military engineer in the army of Gustavus Adolphus, the constructor of bridges and canals (1650–1663); Robert Boyle (1670s); Accademia del Cimento (1657–1667).

4. *Problems of celestial mechanics, the theory of tides*. Kepler (1609); Galileo (1609–1616); Gassendi (1647); Wren (1660s); Halley, Robert Hooke (1670s).

The problems enumerated above cover almost all the subjects of physics at that time.

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[13]The Russian adds a section heading here. There are thus 6 sections in the Russian, five in the original English.

If we compare these main themes with the physical problems that emerged from our analysis of the technical demands presented by communications, industry and war, it becomes quite clear that these physical problems were mainly determined by those demands.

In fact the first group of problems constitutes the physical problems relating to lifting devices and transmission mechanisms that were important to the mining industry and the art of building.

The second group of problems is of great importance for artillery and constitutes the main physical problems relating to ballistics.

The third group of problems is of great importance to the problems of the drainage and ventilation of mines, the smelting of ore, canals and lock construction, intrinsic ballistics and designing the shape of ships.

The fourth group is of enormous importance to navigation.

All these are fundamentally mechanical problems. This of course does not mean that in this period other aspects of the motion of matter were not studied. Optics also began to develop at this time, and the first observations on static electricity and magnetism were made.[14] Nevertheless both by their nature and by their relative weight these problems were of only secondary significance and lagged far behind mechanics in their level of study and mathematical development (with the exception of certain laws of geometrical optics, which were of considerable importance in the construction of optical instruments).

As for optics, it received its main impetus from the technical problems that were of importance, first and foremost, to marine navigation.[15]

We have compared the main technical and physical problems of the era with the topics studied by the leading physicists in the period we are investigating, and we came to the conclusion that these topics were primarily determined by the economic and technical problems that the rising bourgeoisie placed on the agenda.

The development of the productive forces in the age of merchant capital presented science with a number of practical tasks and urgently demanded their solution.

Official science, based in the mediaeval universities, not only made no attempt to solve these problems, but actively opposed the development of the natural sciences.

In the 15th to the 17th centuries the universities were the scientific centres of feudalism. They were not only the bearers of feudal traditions, but the active defenders of those traditions.

In 1655, during the struggle of the master craftsmen with the workers' associations, the Sorbonne actively defended the masters and the guild system, supporting them with "proofs from science and holy writ."

The entire system of pedagogy in the mediaeval universities constituted a closed system of scholasticism. There was no place for natural science in these universities. In Paris, in 1355, it was permitted to teach Euclidean geometry only on holidays.

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[14] [Hessen's note] Investigations into magnetism were directly influenced by the study of the deviation of the compass in the world's magnetic field, which had first been encountered during long-distance sea voyages. Gilbert had already given much attention to problems of the earth's magnetism.

[15] [Hessen's note] In this period optics developed from studying the problem of the telescope.

The main “natural science” manuals were Aristotle’s books, from which all the vital content had been removed. Even medicine was taught as a branch of logics. Nobody was allowed to study medicine unless he had studied logic for three years. True, admittance to the medical examinations also involved a non-logical argument (evidence that the student was a legitimate child), but obviously this illogical question alone was hardly sufficient for a knowledge of medicine, and the famous surgeon Arnold Villeneuve of Montpellier complained that even the professors in the medical faculty were unable, not only to cure the most ordinary illnesses, but even to apply a leech.

The feudal universities struggled against the new science just as fiercely as the obsolete feudal relations struggled against the new progressive modes of production.

For them, whatever could not to be found in Aristotle simply did not exist.

When Kircher (early 17th century) suggested to a certain provincial Jesuit professor that he should look at the newly discovered sunspots through a telescope, the latter replied: “It is useless, my son. I have read Aristotle through twice and have not found anything there about spots on the sun. There are no spots on the sun. They are caused either by the imperfections of your telescope or by the defects of your own eyes.”[16]

When Galileo invented the telescope and discovered the phases of Venus, the scholastic university philosophers did not even want to hear about these new facts, whereas the trading companies requested his telescope, which was superior to those made in Holland.

“I think, my Kepler,” Galileo wrote bitterly on August 19, 1610,[17] “we will laugh at the extraordinary stupidity of the multitude. What do you say to the leading philosophers of the faculty here, to whom I have offered a thousand times of my own accord to show my studies, but who with the lazy obstinacy of a serpent ... have never consented to look either at planets, nor moon, nor telescope?. Verily ... these men close their eyes to the light of truth. These are great matters; yet they do not occasion my surprise. People of this sort think that philosophy is a kind of book ... and that the truth is to be sought, not in the universe, not in nature, but ... by comparing texts.”

When Descartes resolutely came out against the Aristotelian physics of occult qualities and against the university scholasticism, he met with furious opposition from Rome and the Sorbonne.

In 1671 the theologians and physicians of the University of Paris sought a government resolution condemning Descartes’ teaching.

In a biting satire Boileau ridiculed these demands of the learned scholastics. This remarkable document, which gives an excellent description of the state of affairs in the mediaeval universities, is appended in its entirety.[18]

Even in the second half of the 18th century the Jesuit professors in France were not prepared to accept Copernicus’s theories. In 1760, in a Latin edition of Newton’s *Principia*, Le Seur and Jacquier thought it necessary to add the following note: “In his third book Newton assumes that the earth is in motion. Any explication of the author’s views must start from the

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[16]Source not traced.

[17]EN 10, 421-423 241

[18]See Appendix 2

same hypothesis. Thus we are compelled to appear in another's name. But for ourselves, we openly declare that we obey the decrees published by the highest church pontiffs against the motion of the earth."

The universities produced almost exclusively ecclesiastics and jurists.

The church was the international centre of feudalism and itself a large feudal proprietor, possessing no less than one third of the land in Catholic countries.

The mediaeval universities were a powerful weapon of church hegemony.

Meanwhile, the technical problems that we have outlined above demanded enormous technical knowledge, and extensive mathematical and physical studies.

The end of the Middle Ages (mid-15th century) was marked by great advances in the development of the industry created by the mediaeval burghers.

Production, which was increasingly on a mass scale, was improved and diversified; commercial relations became more developed.

If after the dark night of the Middle Ages science again began to develop at a miraculous rate, we owe this to the development of industry (Engels).[19]

Since the time of the Crusades industry had developed enormously and had a mass of new achievements to its credit (metallurgy, mining, the war industry, dyeing), which supplied not only fresh material for observation but also new means of experimentation and enabled the construction of new instruments.

It can be said that from that time systematic experimental science became possible.

Furthermore, the great geographical discoveries, which in the last resort were also determined by the interests of production, supplied an enormous and previously inaccessible mass of material in the realm of physics (magnetic deviation), astronomy, meteorology and botany.

Finally, this period saw the appearance of a mighty instrument for distributing knowledge: the printing press.

The construction of canals, locks and ships, the construction of mines and galleries, their ventilation and drainage, the design and construction of firearms and fortresses, the problems of ballistics, the production and design of instruments for navigation, the development of methods for establishing the position of ships, all demanded people of a totally different type from those being produced by the universities at that time.

In the third quarter of the 16th century, Johann Mathesius already specified that the minimum of knowledge required by a mine-surveyor was proficiency in the method of triangulation and Euclidean geometry, the ability to use a compass, which was essential for constructing galleries, the ability to calculate the correct layout of the mine, and a knowledge of the construction of pumping and ventilation equipment.

He pointed out that engineers with a theoretical education were needed in order to construct galleries and work the mines, since this work was far beyond the powers of an ordinary, uneducated miner.

Obviously, none of this could be learned in the universities of the time. The new science emerged in a struggle with the universities, as an extra-university science.

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[19]Dialetics of Nature, CW, 24,465.

The struggle between the university and the extra-university science that served the needs of the rising bourgeoisie was a reflection in the ideological realm of the class struggle between the bourgeoisie and feudalism.

Step by step, science flourished along with the bourgeoisie. In order to develop its industry, the bourgeoisie required a science that would investigate the properties of material bodies and the manifestations of the forces of nature.

Hitherto science had been the humble servant of the church and had not been allowed to go beyond the limits set by the church.

The bourgeoisie had need of science, and science rebelled against the church together with the bourgeoisie (Engels).[20]

Thus the bourgeoisie came into conflict with the feudal church.

In addition to the professional schools (schools for mining engineers and for training artillery officers), the scientific societies outside the universities were the centers of the new science, the new natural sciences.

In the 1650s the famous Florentine Accademia del Cimento was founded, with the aim of studying nature by means of experiment. It included among its members scientists such as Borelli and Viviani.

The Academy was the intellectual heir of Galileo and Torricelli and continued their work. Its motto was *Provare e riprovare* (verify and verify again through experiment).

In 1645 a circle of natural scientists was formed in London; they gathered weekly to discuss scientific problems and new discoveries.

It was from this gathering that the Royal Society developed in 1661. The Royal Society brought together the leading and most eminent scientists in England, and in opposition to the university scholasticism adopted as its motto: “Nullius in verba”.

Robert Boyle, Brouncker, Brewster,[21] Wren, Halley, and Robert Hooke played an active part in the society.

One of its most outstanding members was Newton.

We see that the rising bourgeoisie brought natural science into its service, into the service of the developing productive forces.

Being at that time the most progressive class, it demanded the most progressive science. The English Revolution gave a mighty stimulus to the development of the productive forces. It became necessary not merely to empirically resolve particular problems, but to establish a synthetic summary and solid theoretical basis for solving, by general methods, all the physical problems raised by the development of the new technology.

And since (as we have already demonstrated) the basic problems were mechanical ones,[22] this encyclopaedic survey of the physical problems amounted to creating a harmonious

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[20]The last three paragraphs paraphrase the Introduction to the English edition of Socialism, Utopian and Scientific MEW 19, 533; CW 24, 290.

[21] Perhaps David Brewster by mistake.

[22] [Hessen] Optics also began to develop during this period, but the main research in optics was subordinated to the interests of maritime navigation and to astronomy. It is important to note that Newton came to study the spectrum by way of the phenomenon of the chromatic aberration in the telescope.

structure of theoretical mechanics which would supply general methods for solving the problems of celestial and terrestrial mechanics.

It was Newton who would elucidate this work. The very title of his most important work indicates that Newton set himself precisely this work of synthesis.

In his introduction to the *Principia* Newton pointed out that applied mechanics and teachings on simple machines had already been elaborated and that his task consisted not in "discussing the various crafts" and solving particular problems, but in providing a teaching about nature, the mathematical bases of physics**.**

Newton's *Principia* are expounded in abstract mathematical language and it would be futile to seek in them an exposition by Newton himself of the connection between the problems that he sets and solves and the technical demands from which they arose.

Just as the geometrical method of exposition was not the method Newton used to make his discoveries, but, in his opinion, was to serve as a worthy vestment for the solutions found by other means, so a work treating of "Natural Philosophy" should not contain references to the "low" source of its inspiration.

We shall attempt to show that the "terrestrial core" of the *Principia* consists precisely of the technical problems that we have analysed above and which fundamentally determined the themes of physical research in that period.

Despite the abstract mathematical character of exposition adopted in the *Principia*, not only was Newton by no means a learned scholastic divorced from life, but he firmly stood at the centre of the physical and technical problems and interests of his time.

Newton's well-known letter to Francis Aston gives a very clear notion of his broad technical interests. The letter was written in 1669 after he had received his professorship, just as he was finishing the first outline of his theory of gravity.[23]

Newton's young friend, Aston, was about to tour various countries in Europe, and he asked Newton to instruct him how to utilise his journey most rationally and what was especially worthy of attention and study in the European countries.

We will cite a brief summary of Newton's instructions.

To thoroughly study the mechanism of steering and the methods of navigating ships.

To survey carefully all the fortresses he should happen upon, their method of construction, their power of resistance, their defence advantages, and in general to acquaint himself with military organisation.

To study the natural resources of the country, especially the metals and minerals, and also to acquaint himself with the methods of their production and refinement.

To study the methods of obtaining metals from ores.

To find out whether it was true that in Hungary, Slovakia and Bohemia, near the town of Eila or in the Bohemian mountains not far from Silesia, there were rivers whose waters contained gold.

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[23] 18 May 1669, *The Correspondence of Isaac Newton, vol. 1,* 9-11. As G.N. Clark points out the letter was in fact written a few months before Newton received his professorship. The letter was also never sent (see Westfall, *Never at Rest,* p. 193).

To find out also whether the method of obtaining gold from gold-bearing rivers by amalgamation with mercury was still a secret, or whether it was now generally known.

In Holland a glass-polishing factory glass had recently been established; he must go to see it.

To find out how the Dutch protected their vessels from worm damage during their voyages to India.

To find out whether clocks were of any use in determining longitude during long-distance sea voyages.

The methods of transmuting one metal into another, iron into copper, for instance, or any metal into mercury, were especially worthy of attention and study.

It was said that in Chemnitz[24] and in Hungary, where there were gold and silver mines, it was known how to transmute iron into copper by dissolving the iron in vitriol, then boiling the solution, which on cooling yielded copper.

Twenty years previously the acid possessing this noble property had been imported into England. Now it was unobtainable. It was possible that they preferred to exploit it themselves in order to transmute iron into copper rather than to sell it.

These last instructions, dealing with the problem of transmuting metals, occupy almost half this extensive letter.

That is not surprising. Alchemistic investigations still abounded in Newton's period. The alchemists are usually imagined to be a kind of magician seeking the philosopher's stone. In reality alchemy was closely bound up with the production of necessities, and the aura of mystery surrounding the alchemists should not conceal from us the real nature of their research.

The transmutation of metals constituted an important technical problem, since there were very few copper mines at that time, and warfare and the casting of cannon demanded much copper.

The developing commerce made great demands on currency that the European gold mines were unable to satisfy. Together with the drive to the east in search of gold, the quest for means of transmuting common metals into copper and gold intensified.

Since his youth Newton had always been interested in metallurgical processes, and he later successfully applied his knowledge and skills in his work at the Mint.

He carefully studied the classics of alchemy and made copious extracts from these works, which show his great interest in all kinds of metallurgical processes.

During the period immediately preceding his work at the Mint, from 1683 to 1689, he carefully studied Agricola's works on metals, and the transmutation of metals was his chief interest.

Newton, Boyle and Locke conducted extensive correspondence on the question of transmuting metals and exchanged formulae for the transmutation of ore into gold.[25]

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[24]Newton writes "Schemnitium" which the editors report refers not to Chemnitz but to Schemnitz (Selmeczbánya) in Hungary.

[25]Appendix 3.

In 1692 Boyle, who had been one of the directors of the East India Company, communicated to Newton his formula for transmuting metal into gold (see appendix III).

When Montague invited Newton to work at the Mint he did so not merely out of friendship, but because he highly valued Newton's knowledge of metals and metallurgy.

It is interesting and important to note that whilst a wealth of material has been preserved relating to Newton's purely scientific activities, none at all has been preserved relating to his activities in the technical sphere.

Not even the materials that would indicate Newton's activities at the Mint have been preserved, although it is well known that he did much to improve the processes of casting and stamping coins.

In connection with Newton's bicentennial, Lyman Newell, who made a special study of the question of Newton's technical activities at the Mint, asked the director of the Mint, Colonel Johnson, for materials relating to Newton's activities in the sphere of the technical processes of casting and stamping.

In his reply Colonel Johnson said that no materials whatever on this aspect of Newton's work had been preserved.

All that is known is his long memorandum to the Chancellor of the Exchequer (1717) on the bi-metallic system and the relative value of gold and silver in various countries. This memorandum shows that Newton's circle of interests was not restricted to technical questions of coin production, but extended to economic problems of currency circulation.

Newton took an active part in, and was an adviser to, the commission for the reform of the calendar, and among his papers is a work entitled "Observations on the Reform of the Julian Calendar," in which he proposes a radical reform of the calendar.

We cite all these facts as a counterweight to the traditional representation of Newton in the literature as an Olympian standing high above all the "terrestrial" technical and economic interests of his time, and soaring only in the lofty realm of abstract thought.

It should be noted, as I have already observed, that the *Principia* certainly afford justification for such a treatment of Newton, which, however, as we see, bears absolutely no relation to reality.

If we compare the range of interests briefly outlined above, we have no difficulty in noting that it embraces almost the entire complex of problems arising from the interests of transport, commerce, industry and war during his period, which we summarised above.

Now let us turn to an analysis of the contents of Newton's *Principia* and consider their relations to the topics of research in physics in that period.

The definitions and axioms or laws of motion expound the theoretical and methodological bases of mechanics.

The first book contains a detailed exposition of the general laws of motion under the influence of central forces. In this way Newton provides a preliminary conclusion to the work of establishing the general principles of mechanics begun by Galileo.

Newton's laws provide a general method for solving the great majority of mechanical problems.

The second book, devoted to the problem of the motion of bodies, addresses a number of problems closely connected with the complex of problems noted above.

The first three sections of the second book are devoted to the problem of the motion of bodies in a resistant medium in relation to various cases of the dependence of resistance upon speed (linear resistance, resistance proportional to the second power of speed and resistance proportional partly to the first and partly to the second power).[26]

In the scholium to the first section Newton notes that linear cases have more mathematical interest than those that are proper to nature, and proceeds to a detailed examination of cases that were observed during the actual motion of bodies in air. As we have shown above when analysing the physical problems of ballistics, whose development was con-nected with the development of heavy artillery, the problems posed and solved by Newton are of fundamental significance to extrinsic ballistics.

The fifth section of the second book is devoted to the fundamentals of hydrostatics and the problems of floating bodies. The same section considers the pressure of gases and the compression of gases and liquids under pressure.

When analysing the technical problems posed by the construction of vessels, canals, water-drainage and ventilation equipment, we saw that all the physical aspects of these problems amount to the fundamentals of hydrostatics and aerostatics.

The sixth section deals with the problem of the motion and resistance of pendulums.

The laws governing the oscillation of mathematical and physical pendulums in a vacuum were discovered by Huygens in 1673 and applied by him to the construction of pendulum clocks.

We have seen from Newton's letter to Aston the importance of pendulum clocks for determining longitude.

The use of clocks for determining longitude led Huygens to the discovery of centrifugal force and the change in acceleration of the force of gravity.

When the pendulum clocks brought by Richer from Paris to Cayenne in 1673 slowed down, Huygens was able at once to explain the phenomenon by a change in acceleration of the force of gravity. The importance Huygens himself attached to clocks is evident from the fact that his chief work is called *On Pendulum Clocks*.

Newton's works continue this course, and just as he progressed from the mathematical case of the motion of bodies in a resistant medium with linear resistance to the study of an actual case of motion, so he progressed from the mathematical pendulum to an actual case of a pendulum's motion in a resistant medium.

The seventh section of the second book is devoted to the problem of the motion of fluids and the resistance of a projected body.

It considers problems of hydrodynamics, including the problem of the efflux of fluids and the flow of water through tubes. As shown above, all these problems are of cardinal importance for the construction of canals and locks and in designing drainage equipment.

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[26]Footnote about : $R = av$, $R = av^2$ und $R = av^2 + bv$

The same section investigates the laws governing the fall of bodies through a resistant medium (water and air). As we know, these problems are of considerable importance in determining the trajectory of a projectile.

The third book of the *Principia* is devoted to the "System of the World." It is devoted to the problems of the motion of the planets, the motion of the moon and its anomalies, acceleration by the force of gravity and its variations in connection with the problem of the irregular movement of chronometers during sea voyages and the problem of high and low tides.

As we have noted above, until the invention of the chronometer the motion of the moon was of cardinal importance for determining longitude. Newton returned to this problem more than once (in 1691). The study of the laws of the moon's motion was of cardinal importance for compiling accurate tables for determining longitude, and the English Council of Longitude instituted a high award for work on the moon's motion.

In 1713 Parliament passed a special bill to encourage research into the determination of longitude. Newton was one of the eminent members of the Parliamentary commission.

As we have pointed out in analysing the sixth section, the study of the motion of the pendulum, begun by Huygens, was of great importance to maritime navigation. In the third book Newton therefore studies the problem of the seconds pendulum, and analyses the motion of clocks during a number of ocean expeditions: that of Halley to St. Helena in 1677, Varin and Deshayes's voyage to Martinique and Guadeloupe in 1682, Couplet's voyage to Lisbon, etc., in 1697, and a voyage to America in 1700.

When discussing the origins of high and low tides, Newton analyses the height of tides in various ports and river mouths and discusses the problem of the height of tides in relation to the location of the port and the form of the high tide.

Even this cursory survey indicates the complete overlap between the topics that concerned physics in that era, which arose out of economic and technical needs, and the contents of the *Principia,* which constitute in the full sense of the word a summary and systematic solution of the entire range of the main physical problems. And since all these problems were of a mechanical nature, it is clear that Newton's chief work was precisely the foundation of terrestrial and celestial mechanics.

The Class Struggle during the English Revolution and Newton's Worldview

It would, however, be a gross oversimplification to derive *every problem* studied by various physicists, and *every task* they solved, directly from economics and technology.

According to the materialistic conception of history, the final determining factor in the historical process is the production and reproduction of actual life.

But this does not mean that the economic factor is the *sole* determining factor. Marx and Engels severely criticised Barth precisely for such a primitive understanding of historical materialism.[27]

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[27]Engels' letter to Konrad Schmidt Aug. 5, 1890 (MEW 37 435f; CW 49, 6).

The economic situation is the basis. But the development of theories and the individual work of a scientist are also affected by various superstructures, such as political forms of the class struggle and its results, the reflection of these battles in the minds of the participants—in political, juridical, and philosophical theories, religious beliefs and their subsequent development into dogmatic systems.

Therefore, when analysing the subjects addressed by physics we took the central, cardinal problems that attracted the greatest attention of scientists in that period. But the foregoing general analysis of the economic problems of the period is inadequate for understanding how Newton's work proceeded and developed and for explaining all the features of his work in physics and philosophy. We must analyse more fully Newton's period, the class struggle during the English Revolution, and the political, philosophical and religious theories as reflections of that struggle in the minds of the contemporaries.

When Europe emerged from the Middle Ages, the rising urban bourgeoisie was its revolutionary class. The position that it occupied in feudal society had become too narrow for it, and its further free development had become incompatible with the feudal system.[28]

The great struggle of the European bourgeoisie against feudalism reached its peak in three important and decisive battles:

The Reformation in Germany, with the subsequent political uprisings of Franz von Sickingen and the Great Peasant War.

The Revolution of 1649–1688 in England.

The Great French Revolution.

There is, however, a great difference between the French Revolution of 1789 and the English Revolution.

In England, feudal relations had been undermined since the Wars of the Roses. The English aristocracy at the beginning of the 17th century was of very recent origin. Out of 90 peers, sitting in Parliament in 1621, 42 had received their peerages from James 1, whilst the titles of the others dated back no earlier than the 16th century.

This explains the close relationship between the upper aristocracy and the first Stuarts. This feature of the new aristocracy enabled it to compromise more easily with the bourgeoisie.

It was the urban bourgeoisie that began the English Revolution and the middle peasantry (yeomanry) of the middle districts brought it to a victorious end.

1688 was a compromise between the rising bourgeoisie and the former great feudal landlords. Since the times of Henry VII, the aristocracy, far from opposing the development of industry, had, on the contrary, tried to benefit from it.

The bourgeoisie was becoming an acknowledged, though modest, part of the ruling classes of England.

In 1648 the bourgeoisie, together with the new aristocracy, fought against the monarchy, the feudal nobility and the dominant church.

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[28]This paragraph is a quote from the Introduction to the English edition of Engels' *Socialism Utopian and Scientific*, MEW 19, 532-3; CW 24, 289.

In the Great French Revolution of 1789, the bourgeoisie, in alliance with the people, fought against the monarchy, the nobility and the dominant church.

In both revolutions the bourgeoisie was the class that actually headed the movement.

The proletariat and the non-bourgeois strata of the urban population either did not yet have different interests from those of the bourgeoisie or did not yet constitute an independently developed class or part of a class.

Therefore, wherever they opposed the bourgeoisie, as, for instance, in 1793–1794 in France, they fought only for the attainment of the interests of the bourgeoisie, even if not in the manner of the bourgeoisie.

All French terrorism was nothing but a plebeian way of dealing with the enemies of the Revolution: absolutism and feudalism. The same may be said of the Levellers movement during the English Revolution.

The revolutions of 1648 and 1789 were not English or French revolutions. They were revolutions on a European scale. They did not represent the victory of one particular class over the old political order, but proclaimed the political order of the new European society.

"The bourgeoisie was victorious in these revolutions, but the *victory of the bourgeoisie* was at that time the *victory of a new social order*, the victory of bourgeois ownership over feudal ownership, of nationality over provincialism, of competition over the guild, of the division of land over primogeniture, of the rule of the landowner over the domination of the owner by the land, of enlightenment over superstition, of the family over the family name, of industry over heroic idleness, of bourgeois law over medieval privileges" (Marx)[29]

The English Revolution of 1649–1688 was a bourgeois revolution.

It brought into power the "capitalist and landlord profiteers."[30] The Restoration did not mean the restoration of the feudal system. On the contrary, in the Restoration the owners of land destroyed the feudal system of land relations. In essence, Cromwell was already doing the work of the rising bourgeoisie. The pauperisation of the population, as the precondition for the emergence of a free proletariat, was intensified after the revolution. It was in this change of the ruling class that the true meaning of the revolution is to be found. The emerging new socio-economic system produced a new governing class. Herein lies the main difference between Marx's interpretation and that of traditional English historians, particularly Hume and Macaulay.

Like a true Tory, Hume viewed the importance of the 1649 revolution and the Restoration, and then the revolution of 1688, only in relation to the destruction and reestablishment of order.

He severely condemned the upheaval caused by the first revolution and welcomed the Restoration as the reestablishment of order. He sympathised with the 1688 revolution as a

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[29]Except for one sentence on the Levellers, the last 5 paragraphs paraphrase Marx "The Bourgeoisie and the Counter-Revolution," Neue Rheinische Zeitung, No. 169, 15. December 1848 (MEW 6, 107; CW 8, 161).

[30] "Die 'glorious Revolution' brachte mit dem Oranier Wilhelm III. die grundherrlichen und kapitalistischen Plusmacher zur Herrschaft." (MEW 23, 751; CW 35,713–14).

constitutional act, although he did not consider that it had simple restored the old freedom. It had begun a new constitutional era, giving "an ascendant to popular principles."[31]

To Macaulay the revolution of 1688 was closely connected with the first revolution. But for him, the revolution of 1688 was "the glorious revolution" precisely because it was a constitutional one.

He wrote his history of 1688 immediately after the events of 1848, and his fear of the proletariat and its possible victory is evident throughout. He proudly and joyfully relates that, when depriving James II of his throne, Parliament observed all the detailed precedents and even sat in the ancient halls in robes prescribed by ritual.

Law and constitution are regarded as extra-historical essences with no connection to the dominant class, a view that prevents an understanding of the true essence of the revolution.

Such was the distribution of class forces after the English Revolution. The fundamental philosophical trends in the period immediately before and after the English Revolution were:

Materialism, whose beginning can be traced to Bacon, was represented in Newton's period by Hobbes, Toland, Overton, and partly by Locke.

Idealistic sensualism, represented by Berkeley (H. More was closely associated with this view).

In addition, a fairly strong trend of moral philosophy and Deism, represented by Shaftesbury and Bolingbroke.

All these philosophical trends existed and developed in the complex conditions of the class struggle whose main features have been outlined above.

From the time of the Reformation the church became one of the chief bulwarks of the King's power. The church organisation was a component part of the state system, and the King was the head of the State Church. James I was fond of saying: "No Bishop, no King."

Every subject of the English King had to belong to the State Church. Anyone who did not belong to it was regarded as committing an offence against the state.

The struggle against the absolute power of the King was at the same time a struggle against the centralism and absolutism of the dominant State Church, and therefore the political struggle of the rising bourgeoisie against absolutism and feudalism was waged in the guise of a struggle for religious democracy and tolerance.

The collective name "Puritans" applied to all supporters of the purification and democratisation of the ruling church. However, among the Puritans a distinction should be made between the more radical Independents and the more conservative Presbyterians. These two trends formed the basis of political parties.

The supporters of the Presbyterians came mainly from among the well-to-do merchants and the urban bourgeoisie. The Independents drew their supporters from the ranks of the rural and urban democracy.

Thus both the class struggle of the bourgeoisie against absolutism and the struggle of the trends within the ranks of the bourgeoisie and peasantry were waged under religious slogans.

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[31] Hume: *History of England*, Chapt LXXI.

The religious trends of the bourgeoisie were yet further strengthened by the development of materialistic teachings in England.

Let us briefly review the main stages of the development of materialism in this period and its most important representatives.

Bacon was the father of materialism. His materialism arose out of a struggle with medieval scholasticism. He wanted to release humanity from the old traditional prejudices and to create a method for controlling the forces of nature. His teachings contain the germs of the many-sided development of this doctrine. "Matter smiles with its sensuous, poetic glamour at all humanity" (Marx).[32]

In the hands of Hobbes, materialism became abstract and one-sided. Hobbes did not develop Bacon's materialism, but only systematised it.

Sensuality lost its bright colours and was transformed into the abstract sensuality of a geometrist. All the diverse forms of motion were sacrificed to mechanical motion. Geometry was proclaimed as the dominant science (Marx).[33]

The living spirit was excised from materialism, and it became misanthropic. This abstract, calculating, formally mathematical materialism could not stimulate revolutionary action.

That is why the materialistic theory of Hobbes accorded with his monarchical views and defence of absolutism. After the victory of the Revolution of 1649 Hobbes went into exile.[34]

But alongside the materialism of Hobbes there existed another materialistic movement, indissolubly bound up with the true revolutionary movement of the Levellers and headed by Richard Overton.

Richard Overton was the loyal companion-in-arms of the Levellers' leader, John Lilburn, the fiery exponent of revolutionary ideas and brilliant political pamphleteer. Unlike Hobbes, he was a practical materialist and revolutionary.

The fate of this warrior-philosopher is curious. Whilst the name of Hobbes is widely known and to be found in all the philosophy textbooks, not a single word can be found about Overton, not only in the most detailed bourgeois primer of philosophy, but even in the most complete biographical encyclopaedias.[35] Thus the bourgeoisie takes revenge on its political opponents.

Richard Overton did not write much. He exchanged too often the pen for the sword and philosophy for politics. His treatise *Man Wholly Mortal*[36] was first published in 1643, and the second edition appeared in 1655. It is a blatantly materialistic and atheistic essay. Immediately after its appearance it was condemned and banned by the Presbyterian Church.

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[32]Holy Family MEW 2, 135.

[33]Holy Family MEW 2, 135

[34]Hobbes went into exile in the Fall of 1640 and returned in 1651.

[35]As G.N.Clarke points out, Overton is in fact mentioned in the *Dictionary of National Biography*; but, as he doesn't point out, the *Encyclopedia Britannica* (11th ed.) has no entry—nor does the Edinburgh *Cyclopedia*.

[36]Richard Overton, *Man Wholly Morrtal*, London 1655; Hessen's quotes from and about Overton are taken from Eduard Bernstein, *Sozialismus und Demokratie in der großen englischen Revolution*, chap. 8. (4th ed. Stuttgart: Dietz, 1922) pp. 115-119.

The manifesto of the Presbyterian Assembly "against unbelief and heresy" called down all curses on Richard Overton's head. "The chief representative of the terrible teaching of materialism," declares the manifesto, "that denies the immortality of the soul, is Richard Overton, the author of the book on the mortality of man."

We will not go into the details of Overton's teaching and its fate—a most interesting page in the history of English materialism—but will only mention one point from the publication mentioned, in which Overton formulated very clearly the basic principles of his materialistic worldview.

In criticising the opposition between the body as inert matter and the soul as the active, creative principle, Overton writes:

"The *Form* is the *Form* of the *Matter,* and the *Matter* the *Matter* of the *Form*; neither of themselves, but each by other, and both together make *one Being*"

"All that is created, is elemental." (Overton uses the term "elements" in the sense of the ancient Greeks: water, air, earth) "But all that is created is material: for that which is not material, is nothing."[37]

Unlike in England, materialism on French soil was the theoretical banner of French republicans and terrorists, and formed the basis of the "Declaration of the Rights of Man."

In England the revolutionary materialism of Overton was the teaching of only one extreme group, while the main struggle was waged under religious slogans.

English materialism as preached by Hobbes proclaimed itself to be a philosophy fit for scientists and educated people, in contrast to religion, which was good enough for the uneducated masses, including the bourgeoisie.

Together with Hobbes, materialism, shorn of its actual revolutionary nature, came to the defence of royal power and absolutism and encouraged the repression of the people.

Even with Bolingbroke and Shaftesbury the new deistic form of materialism remained an esoteric, aristocratic teaching.

Therefore the "misanthropic" materialism of Hobbes was hateful to the bourgeoisie both for its religious heresy and for its aristocratic connections.

Accordingly, in opposition to the materialism and deism of the aristocracy, it was those Protestant sects who had provided the cause and the fighters against the Stuarts who also provided the main fighting forces of the progressive middle class (Engels).[38]

But still more hateful to the bourgeoisie than Hobbes's esoteric materialism was Overton's materialism, under whose banner the political struggle against the bourgeoisie was waged, a materialism that turned into militant atheism and fearlessly opposed the very bases of religion. It was in these circumstances that Newton's worldview was formed.

Newton was a typical representative of the rising bourgeoisie, and his worldview reflected the characteristic features of his class. We may quite rightly apply to him the description that Engels applied to Locke. He too was a typical child of the class compromise of 1688.[39]

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[37]*Man Wholly Mortal* 1655, pp. 10, 20–21.

[38]The last 5 paragraphs paraphrase the Introduction to the English edition of *Socialism Utopian and Scientific,* MEW 19, 536; CW 27, 293–294.

Newton was the son of a small farmer. Until his appointment as Warden of the Mint (1699), he had a very modest position in the university and in society. He also belonged to the middle class through his connections, but philosophically he was closest to Locke, Samuel Clarke and Bentley.

In his religious beliefs Newton was a Protestant and there are many grounds for assuming that he belonged to the Socinian sect. He was an ardent supporter of religious democracy and tolerance. We shall see below that Newton's religious beliefs were a component part of his worldview.

In his political views Newton belonged to the Whig Party. During the second revolution Newton was a Member of Parliament for Cambridge from 1689 to 1690. When the conflict arose over the possibility of swearing allegiance to "the illegitimate ruler"—William of Orange—which even led to riots in Cambridge, Newton, who as Member of Parliament for Cambridge University had to bring the University to swear allegiance, insisted on the necessity of swearing allegiance to William of Orange and recognizing him as King.

In his letter[40] to Dr. Covel Newton adduced three arguments in favour of swearing allegiance to William of Orange, which were to remove any doubts in this regard on the part of members of the University who had previously sworn fidelity to the deposed King.

Newton's reasoning and arguments are strongly reminiscent of Macaulay's and Hume's opinions cited above.

This ideological cast of mind of Newton, who was a child of his class, explains why the latent materialistic germs of the *Principia* did not grow to become a harmonious system of mechanical materialism, like the physics of Descartes, but were interwoven with his idealistic and theological views, to which, on philosophical questions, even the material elements of Newton's physics were subordinated.

The significance of the *Principia* is not limited to technical matters alone. Its very name indicates that it forms a system, a worldview. Therefore it would be incorrect to confine an analysis of the contents of the *Principia* merely to determining its intrinsic connection with the economics and technology of that period, which served the needs of the rising bourgeoisie.

Modern natural science owes its independence to its freedom from teleology. It recognises only the causative study of nature.

One of the battle slogans of the Renaissance was: "True knowledge is knowledge by causes" (*vere scire per causas scire*).[41]

Bacon emphasised that the teleological view is the most dangerous of *idola*. The true relations of things are found in mechanical causation. "Nature knows only mechanical causation, to the investigation of which all our efforts should be directed."

A mechanistic conception of the universe necessarily leads to a mechanistic conception of causation. Descartes laid down the principle of causation as "an eternal truth."

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[39] Engels to Conrad Schmidt 27.10.1890.

[40] 21 Feb.1689, The Correspondence of Isaac Newton. Vol. I ed. By H.W. Turnbull, Cambridge University Press 1959, p.12.

[41] Bacon Nov. Org. II §2:

Mechanistic determinism came to be generally accepted on English soil, although it was often interwoven with religious dogma (of the "Christian necessarian" sect, to which Priestley belonged). This peculiar combination—so characteristic of thinkers of the English type—is also found in Newton.

The universal acceptance of the principle of mechanical causation as the sole and basic principle for the scientific investigation of nature was brought about by the mighty development of mechanics. Newton's *Principia* is a grandiose application of this principle to our planetary system. "The old teleology has gone to the Devil,"[42] but so far only in the realm of inorganic nature, of terrestrial and celestial mechanics.

The basic idea of the *Principia* consists in the conception of the motion of the planets as a consequence of the unity of two forces: one directed towards the sun, and the other that of the original impulse. Newton left this original impulse to God but "forbade Him further interference in His solar system" (Engels).[43]

This unique "division of labour" in the government of the universe between God and causation was characteristic of the way in which the English philosophers interwove religious dogma with the materialistic principles of mechanical causation.

The acceptance of the modality of motion, and the rejection of moving matter as *causa sui* was inevitably bound to bring Newton to the conception of the original impulse. From this perspective, the conception of divinity in Newton's system is by no means incidental but is organically connected with his views on matter and motion, as well as with his views on space, in the development of which he was greatly influenced by Henry More.

It is at this point that the entire weakness of Newton's general philosophical conception of the universe becomes apparent. The principle of pure mechanical causation leads to the notion of the divine element. "The absurd infinity" of the universal chain of mechanical determinism ends in the original impulse, thus opening the door to teleology.

Thus, the importance of the *Principia* is not confined to purely physical problems, but is also of great methodological interest.

In the third book of the *Principia* Newton expounds a "conception of the universe." The general scholium to the third book (third edition) proves the necessity of a divine power as the organizing, moving and directing element of the universe.

We shall not go into the question of the authorship of this scholium nor of the role of Cotes and Bentley in the publication of the *Principia*. There is extensive literature on this question, but the letters from Newton quoted below undeniably prove that Newton's theological views were by no means a mere appendage to his system and were not forced upon him by Cotes or Bentley.

When Robert Boyle died in 1692 he left a sum yielding £50 per annum in order that every year eight lectures would be delivered in one of the churches in England proving the irrefutability of Christianity and repudiating unbelief.

Bentley, Chaplain of the Bishop of Worcester, had to deliver the first series of these lectures. He decided to devote the seventh and eighth to proving the necessity of the existence of

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[42]Engels, *Dialectics of Nature*, MEW 20: 466: "Die alte Telelologie ist zum Teufel"; CW 25, 475.

[43] Engels, *Dialectics of Nature*, MEW 20: 471, CW 25, 480.

divine providence, basing the proof on a consideration of the physical principles of the creation of the world as stated in Newton's *Principia*.

While preparing these lectures, he encountered a number of physical and philosophical difficulties, which he requested the author of the *Principia* to explain.

Newton replied in detail to Bentley's questions in four letters which provide a valuable source of information on Newton's views on the cosmological problem.

The chief difficulty Bentley asked Newton about was how to repudiate the materialistic argument, already propounded by Lucretius, that the creation of the world could be explained by purely mechanical principles, if it is assumed that matter possesses an immanently inherent attribute of gravity and is evenly distributed in space.

In his letters Newton pointed out in detail to Bentley how this materialistic argumentation can be overcome.

It is not difficult to see that this discussion was essentially about the theory of the evolution of the universe, and on this question Newton was resolutely opposed to the materialistic conception of evolution.

"When I wrote my Treatise about our Systeme," wrote Newton to Bentley, "I had an Eye upon such Principles as might work with considering Men, for the beliefe of a Deity.[44]

If matter were uniformly distributed in finite space, then, owing to its force of gravity, it would accumulate into one large spherical mass. But if matter were distributed in infinite space, then it could, in obedience to the force of gravity, form masses of varying magnitude.

However, in no case can it be explained by natural causes how the luminous mass—the sun—is in the centre of the system and precisely in the position in which it is placed.

Therefore the only possible explanation lies in the acknowledgment of a divine creator of the universe, who wisely distributed the planets in such a manner that they receive the light and warmth necessary to them."

Going further into the question of whether planets could be set in motion as a consequence of natural causes, Newton pointed out to Bentley that planets could be set in motion as a consequence of the force of gravity, which was a natural cause, but could never achieve periodical rotation along closed orbits, which would require a tangential component. Therefore, Newton concludes, the actual paths of the planets and their structure can in no way be explained by natural causes, and hence, an enquiry into the structure of the universe leads to the presence of an intelligent divine principle.

Furthermore, when discussing the question of the stability of the solar system, Newton pointed out that such a marvellously organized system, in which the speed and mass of bodies are selected in such a manner as to maintain stable equilibrium, could only be created by divine reason.

This conception and Newton's appeal to divine reason as the highest principle, organizer and prime moving force of the universe is by no means incidental but is the inevitable consequence of his conception of the principles of mechanics.

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[44]Letter to Bently, Dec. 10, 1692, *Correspondence* III, 233.

Newton's first law of motion attributed to matter the faculty of maintaining that state in which it exists.

As Newton considered only the mechanical form of motion, his conception of the state of matter is synonymous with the condition of rest or mechanical change of place.

Matter that is not acted upon by external forces can exist either in a state of rest or in a state of rectilinear, uniform motion. If a material body is at rest, then only an external force can bring it out of that state.

If, however, a body is in motion, then only an external force can change that motion.

Thus, motion is not an immanently inherent attribute of a body, but is a mode which matter may or may not possess.

In this sense Newton's matter is inert in the full meaning of the word. An external impulse is always necessary to set it in motion or to alter or end this motion.

Moreover, as Newton accepts the existence of an absolute, motionless space, according to him inertia is possible also as absolute inertia, and thus the existence of absolutely motionless matter, not merely motionless within the given frame of reference, is physically possible.

It is clear that such a conception of the modality of motion must inevitably lead to the introduction of an external motive force, and in Newton this role is performed by God.

It is very important to note that, in principle, not only is Newton not opposed to the idea of endowing matter with specific attributes, but, contrary to Descartes, declares density and inertia to be "innate properties of matter."

Thus, by depriving motion of the property of being an attribute of matter, and recognizing it only as a mode, Newton consciously deprives matter precisely of that inalienable property without which the structure and origin of the world cannot be explained by natural causes.

If we contrast Newton's point of view with that of Descartes, the difference in their beliefs is immediately apparent.

"I freely acknowledge," the latter declares in his *Principia*, "that I recognize no matter in corporeal things apart from that which the geometers call quantity, and take as the object of their demonstrations, i.e that to which every kind of division, shape and motion is applicable. Moreover, my consideration of such matter involves absolutely nothing apart from these divisions, shapes and motions; and even with regard to these, I will admit as true only what has been deduced from indubitable comon notion so evidently that it is fit to be considered as a mathematical demonstration. And since all natural phenomena can be explained in this way, as will become clear in what follows, I do not think that any other principles are either admissible or desirable in physics."[45]

In his physics, Descartes does not recognize any supernatural causes. Therefore Marx points out that the mechanistic French materialism was close to Descartes' physics, in opposition to his metaphysics.

Descartes' Physics could play that role only because "within his physics, matter is the sole substance, the sole basis of being and of knowledge" (Marx).[46]

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[45]Principia Philosophiae II, §64 (AT VIII, 78-79) CSM 1, 247.

[46]Holy Family MEW 2, 133 CW 4 124(?)

In the third part of his *Principia* Descartes also gives a picture of the development of the universe. The difference in Descartes' position consists in his detailed consideration of the historical genesis of the universe and the solar system in accordance with the principles mentioned above.

It is true that Descartes also considers motion only as a mode of matter, but, in contrast to Newton, for him the supreme law is the law of conservation of quantity of motion.

Individual material bodies can acquire and lose motion, but the general quantity of motion in the universe is constant.

Descartes' law of the conservation of quantity of motion includes the assumption that motion is indestructible.

It is true that Descartes understood indestructibility in a purely quantitative sense, and this mechanical formulation of the law of conservation of motion is not accidental but arises from the fact that Descartes, like Newton, considers that all varieties of motion consist of mechanical change of place. They do not consider the problem of the transformation of one form of motion into another, and, as we shall see in the second part of this paper, there are profound reasons for this.

Engels' great merit lies in the fact that he considered the process of the motion of matter as the eternal passing of one form of material motion into another. This enables him not only to establish one of the basic theses of dialectic materialism, i.e., the inseparability of motion from matter, but also to bring the conception of the law of conservation of energy and quantity of motion to a higher level.

We shall return to this problem in the second part of this paper.

Descartes, like Newton, also introduced God, but he needed God only to prove that the quantity of motion in the universe remains constant.

He not only refused to admit the conception of an external impetus from God in regard to matter, but, on the contrary, considered that constancy is one of the basic attributes of the deity; hence, we cannot assume any inconstancy in his creations, since by assuming inconstancy in his creations we also assume inconstancy in him.

Thus Descartes' reason for introducing a deity is different from Newton's, but his conception also requires a deity since Descartes, too, does not maintain an entirely consistent view of the self-movement of matter.

During the period when Descartes and Newton were elaborating their conceptions of matter and motion, although somewhat later (the 1690s), we find in John Toland a far more consistent materialistic conception of the relation between matter and motion.

Criticising the views of Spinoza, Descartes and Newton, Toland directed his chief attack against the conception of the modality of movement.

"*Motion*," contended Toland in his fourth letter to Serene, "is *essential to Matter*, that is to say, as inseperable from its Natur as Impenetrability or Extension, and that it ouight to make a part of its Definition."

"This Notion alone," Toland quite justly avers, "accounts for the same Quantity of Motion in the Universe … it solves all the Difficultys about the moving Force…"

The principle of the self-movement of matter was fully developed in the dialectical materialism of Marx, Engels and Lenin.

The entire progress of modern physics demonstrates the truth of this teaching. Modern physics is increasingly confirming the view that motion and matter are inseparable.

Modern physics rejects absolute rest.

The universal significance of the law of the conservation and transformation of energy increasingly corroborates Engels' conception of the correlation of forms of motion of matter. This is the only conception that provides a true understanding of the law of the transformation of energy, as it synthesises the quantitative aspect of this law with its qualitative aspect, uniting it organically with the self-movement of matter.

The way in which the law of inertia and the conception of inert matter are connected with Newton's absolute space has been indicated above.

However, Newton did not confine himself to a physical conception of space, but also provided a philosophical-theological conception.

Dialectical materialism considers space as a form of existence of matter. Space and time are the fundamental conditions for the existence of all being, and therefore space is inseparable from matter. All matter exists in space, but space exists only in matter. Empty space separated from matter is only a logical or mathematical abstraction, the fruit of our thought, to which no real thing corresponds.

According to Newton's thesis, space can be separated from matter, and absolute space preserves its absolute properties precisely because it exists independently of matter.

Material bodies exist in space, as in a kind of receptacle. Newton's space is not a form of the existence of matter, but only a receptacle that is independent of these bodies and exists independently.

Such is the conception of space as laid down in the *Principia*. Unfortunately, we cannot enter here into a detailed analysis of this conception. We will only note that such a conception is closely connected with the first law of motion.

Having thus defined space as a receptacle, separated from matter, Newton, naturally, asks himself what is the essence of this receptacle.

In solving this question Newton concurs with H. More, who held the view that space is "the sensorium of God" (*sensorium dei*).

In this matter Newton also differs fundamentally from Descartes, who developed the conception of space as a physical body.

The unsatisfactory nature of Descartes' conception lies in the fact that he identified matter with geometric volume.

Whilst Newton separated space from matter, Descartes, by materialising geometrical forms, deprived matter of all properties except extension. This, of course, is also incorrect, but this conception did not lead Descartes in his physics to the same conclusions as Newton.

What is there in space devoid of matter? asks Newton in Question 28 of his *Optics*. How can it be that in Nature everything is consistent and whence arises the harmony of the world? Does it not follow from the phenomena of Nature itself that there is an incorporeal, intelligent, omnipresent being for whom space is his sensorium, through which he perceives things and comprehends their very essence?[47]

Thus we see that in this question too Newton firmly adopts the viewpoint of theological idealism.

Thus the idealistic views of Newton are not incidental, but organically bound up with his conception of the universe.

Whilst there is a distinct dualism in Descartes' physics and metaphysics, Newton, particularly in his later period, not only demonstrates no desire to separate his physical conception from his philosophical one, but, on the contrary, even attempts in his *Principia* to justify his religious-theological views.

In so far as the *Principia* mostly arises from the demands of the economy and technology of the era and investigates the laws of the motion of material bodies, it undoubtedly contains elements of healthy materialism.

But the general defects of Newton's philosophical conception outlined above, and his narrow mechanical determinism, not only do not permit him to develop these elements, but on the contrary thrust them into the background of his general religious-theological conception of the universe.

Hence, in his philosophical views, as in his religious and political views, Newton was a child of his class. He ardently opposed materialism and unbelief.

In 1692, after the death of his mother and the fire that destroyed his manuscripts, Newton was in a state of depression. At that time he wrote to Locke, with whom he corresponded on various theological matters, a caustic letter on his philosophical system.

In his letter of 16 September 1693 he asked Locke to forgive him for that letter and for having thought that Locke's system offended moral principles. Newton particularly asked forgiveness for having considered Locke a follower of Hobbes.[48] Here is confirmation of Engels' statement that Hobbes's materialism was hateful to the bourgeoisie.

Overton's materialism could not even be mentioned—after all, he was almost a Bolshevik.

When Leibniz, in his letters to the Princess of Wales, accused Newton of materialism because he considered space as the sensory of a deity, by which it perceives things, which consequently do not wholly depend on it and are not created by it, Newton fiercely protested against such accusations. Clarke's polemics with Leibniz were aimed at rehabilitating Newton from this accusation (see appendix 5)

If in the realm of physics Newton's research remained mainly within the bounds of one form of motion, that is, mechanical change of place, and therefore contained no conception of development and transition from one form of motion to another, then the conception of development is also entirely absent from his views on nature as a whole.

Newton concludes the first period of the new natural science in the field of the inorganic world. It is a period when the available material was mastered. He achieved great results in the realm of mathematics, astronomy and mechanics, particularly thanks to the work of Kepler and Galileo, which Newton completed.

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[47]*Opticks* 369-70.

[48]See Appendix 4

But a historical view of nature is absent. It does not exist as a system in Newton. Natural science, which is basically revolutionary, comes to a halt in face of a conservative nature that remains throughout the ages in the state in which it was created.

Not only is there no historical view of nature in Newton, but his system of mechanics does not even contain a law of the conservation of energy. At first sight, this is even harder to understand since the law of conservation of energy is a simple mathematical consequence of the central forces that Newton considered.

Furthermore, Newton considers, for instance, cases of oscillation, for which Huygens, when studying the question of the centre of oscillations, had implicitly formulated the law of the conservation of energy.

It is quite obvious that it was not any lack of mathematical genius or limitation in his physical horizon that prevented Newton from enunciating this law, even in the form of an integral of living forces.[49]

In order to explain this we must consider the question from the viewpoint of our Marxist conception of the historical process. Such an analysis will enable us to link this question to the problem of the transformation of one form of motion into another, the solution to which was provided by Engels.

Engels' Conception of Energy and the Lack of The Law of Conservation of Energy in Newton

In analysing the problems of the interrelations between matter and motion in Newton, we saw that Toland took the view that motion was inseparable from matter. Nevertheless, the simple recognition of the inseparability of matter from motion is still far from resolving the problem of studying the forms of motion of matter.

In nature we observe an endless variety of forms of motion of matter. If we pause to consider the forms of motion of matter studied by physics we see that here too are a number of different forms of motion (mechanical, thermal, electromagnetic).

Mechanics studies the form of motion that consists in the simple change of place of bodies in space.

Nevertheless, in addition to this form of motion there are a number of other forms of motion of matter, in which mechanical change of place recedes to the background by comparison with new specific forms of motion.

Although the laws of the motion of electrons are connected with their mechanical change of place, they do not amount to their simple change of place in space.

Consequently, in distinction from the mechanical viewpoint, which regards the main task of natural science as the reduction of the entire complex aggregation of the motion of matter to one form of mechanical change of place, dialectical materialism regards the main task of natural science as the study of forms of motion of matter in their interconnections, interactions and development.

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[49] Footnote on *vis viva*.

Dialectical materialism understands motion as change in general. Mechanical change of place is only one, partial form of motion.

In nature absolutely isolated pure forms of motion are never encountered in real matter. Every real form of motion, including, of course, mechanical change of place, is always bound up with the transformation of one form of motion into another.

Hitherto physics has remained within the bounds of studying one form of motion, the mechanical form, and, as we have seen, this is what constitutes the distinctive nature of physics in Newton's period; the problem of the interrelations between this and other forms of motion could not really be posed. And when such a problem was posed there was always a tendency to hypostatise precisely this most simple and most fully studied form of motion and to present it as the sole and universal aspect of motion.

Descartes and Huygens adopted this position, and Newton essentially associated himself with it.

In the introduction to the *Principia* Newton notes, "I wish we could derive the rest of the phaenomena of Nature by the same kind of reasoning from mechanical principles." (Newton deduced the motion of the planets from these laws in the third book.) "For I am induced by many reasons to suspect," he continues, "that they may all depend upon certain forces by which the particles of bodies, by some causes hitherto unknown, are either mutually repelled towards each other and cohere in regular figures, or are repelled and recede from each other."[50]

The development of large-scale industry made it necessary to study new forms of motion of matter and exploit them for the needs of production.

The steam engine gave enormous impetus to the development of the study of the new, thermal form of motion. The history of the development of the steam engine is of importance to us in two regards.

First we shall investigate why the problem of the steam engine emerged during the development of industrial capitalism and not during the development of merchant capital. This will explain why the steam engine became the central object of investigation only in the period immediately after Newton, even though the invention of the first steam engine dates from Newton's period (Ramsay's patent in 1630).

Thus we see that the connection between the development of thermodynamics and the steam engine is the same as that between the technical problems of Newton's period and his mechanics.

But the development of the steam engine is also of interest for another reason.

In distinction from mechanical machines (the block, the windlass, the lever) in which one aspect of mechanical motion is converted into another aspect of the same mechanical change of place, by its very essence the steam engine is based on the conversion of one form of motion (thermal) into another (mechanical).

Thus, the development of the steam engine also inevitably raises the problem of the transformation of one form of motion into another, which we do not find in Newton and which is closely bound up with the problem of energy and its transformation.

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[50]Newton *Principia* Preface (not Introduction) (Motte A2v).

We shall first investigate the main stages in the development of the steam engine in connection with the development of the productive forces.

Marx noted that the mediaeval trade of the first merchant towns was of an intermediary character. It was founded on the barbarism of the producing nations, for whom those towns and the merchants played the role of middlemen.

So long as merchant capital played the role of middleman in the exchange of products between undeveloped countries, commercial profit was not merely the result of cheating and deceit, but directly originated from them.

Later merchant capital exploited the difference between the prices of production of various countries. In addition, as Adam Smith emphasises, during the first stage of its development merchant capital is chiefly a contractor and supplies the needs of the feudal landlord or the oriental despot, concentrating the main mass of surplus-product in its own hands and being relatively less interested in the prices of commodities.

This explains the enormous profits of mediaeval trade. The Portuguese expedition of 1521 purchased cloves for two or three ducats and sold them in Europe at 336 ducats. The total cost of the expedition amounted to 22,000 ducats, the receipts were 150,000 ducats, the profits 130,000, i.e., about 600 per cent.

At the beginning of the 17th century the Dutch purchased cloves at 180 guldens for 625 pounds, and sold them in the Netherlands for 1,200 guldens.

The greatest percentage of profit came from those countries that were completely subject to Europeans. But even in the trade with China, which had not lost its independence, the profits reached 75 to 100 per cent.

When merchant capital possesses overwhelming hegemony everywhere, it constitutes a system of despoliation.

The high rates of profit were maintained in the 17th and the beginning of the 18th centuries.

This was because the extensive trade of the late Middle Ages and the beginning of the modern era was mainly monopolistic commerce. The British East India Company was closely connected with state power. Cromwell's navigation act strengthened the monopoly of British trade. It was from that time that the gradual decline of Holland as a naval power began and a solid basis was laid to England's maritime hegemony.

Thus, so long as the dominant form of capital was merchant capital, attention was mainly directed, not so much to improving the actual process of exchange, but to consolidating the monopolistic position and dominating the colonies.

Developing industrial capitalism immediately turned its attention to the process of production. The free competition within the country, which the British bourgeoisie achieved in 1688, immediately made it necessary to consider the question of costs of production.

As Marx observed, large-scale industry universalised competition and made protective tariffs a mere palliative.

It was necessary not only to produce sufficient quantities of high-quality commodities, but to produce them as cheaply as possible.

The process of reducing the cost of the production of commodities was directed along two lines: the ever increasing exploitation of labour power (the production of absolute surplus value) and the improvement of the production process itself (relative surplus value). The invention of machines not only failed to reduce the working day but, on the contrary, as a powerful means of increasing the productivity of labour, as an instrument of capital, it became a means for excessively extending the working day.

We shall trace this process in the steam engine. But before turning to an analysis of the history of the development of the steam engine, we must elucidate what we mean by an engine since on this question the Marxist point of view differs radically from that of other researchers.

At the same time, in order to elucidate the essence of the industrial revolution, which made the steam engine so prominent, it is necessary to have a clear understanding of the role played by the steam engine in the industrial revolution.

It is widely believed that the steam engine created the industrial revolution. Such an opinion is erroneous. Manufacture developed out of handicrafts in two ways. On the one hand it arose from the combination of heterogeneous independent handicrafts, which lost their independence, and on the other hand it arose from the co-operation between craftsmen in the same craft, broke down the particular process into its component parts and led to a division of labour within manufacture.

The starting point in manufacture is labour power.

The starting point in large-scale industry is the means of labour. Of course, the problem of the motive power is also important for manufacture, but the revolutionisation of the entire process of production, which had been prepared by the detailed division of labour within manufacture, was brought about not by the motive power but by the mechanism of implementation.

Every machine consists of three basic parts: the motive power, the transmitting mechanism and the tool.[51]

The essence of a historical view of the definition of a machine is precisely the fact that in various periods a machine has various purposes.

Vitrivius's definition of a machine remained valid until the industrial revolution. For him a machine was "a coherent combination of joinery most capable of moving loads."[52]

Consequently the basic instruments serving these ends: the inclined plane, the windlass, the block the lever, were called simple machines.

In his introduction to the *Principia,* Newton attributes the teaching about five simple machines—the lever, the wheel, the block, the windlass, the wedge—to the applied mechanics developed by the ancients.

This is the source of the widespread opinion in English literature that an instrument is a simple machine and a machine, a complex instrument.

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[51]MEW 23, 393: "Alle entwickelte Maschinerie besteht aus drei wesentlich verschiednen Teilen, der Bewegungsmaschine, dem Transmissionsmechanismus, endlich der Werkzeugmaschine oder Arbeitsmaschine."

[52] De Achitectura 10.1.1: "Machina est continens e materia coniunctio maximas ad onerum motus habens virtutes."

However, it is not entirely a question of simplicity and complexity. The essence of the matter is that the introduction of a tool designed to grip and expediently change the object of labour brought about a revolution in the very process of production.

The other two parts of the machine exist in order to set the tool in motion.

Thus, it is clear that a great gulf divides the machines known to Vitruvius, which accomplish only the mechanical change of place of the finished products, from the machines of large-scale industry, whose function consists in a complete change in the original material of the product.

The fruitful nature of Marx's definition is especially clear if we compare it with the definitions of a machine found in the literature.

In his *Theoretical Kinematics* Reuleaux[53] defines a machine as a combination of bodies capable of resistance, which is so arranged that by its means mechanical natural forces can be compelled to act under certain motions.

This definition is equally applicable to Vitruvius's machine and to the steam engine. Although there are difficulties in applying it to the steam engine.

Sombart's definition of a machine suffers from the same defect. Sombart calls the machine a means or a complex of means of labour, operated by a man, the purpose of which is the mechanical rationalisation of labour. What distinguishes the machine as a means of labour from an instrument of labour is precisely the fact that the former is operated by a man, whereas the latter serves a man.

This definition is inadequate precisely because it bases the distinction between an instrument and a machine on the fact that the one serves a man and the other is operated by a man. This definition, which at first sight is based on a socio-economic sign, not only fails to distinguish between the period in which the simple instrument predominates and the period in which the machine method of production predominates, but creates the quite absurd notion that the essence of the machine consists in its being operated by a man.

Thus an imperfect steam engine demanding the continual operation of a man (in Newcomen's first engines a boy had to continually open and close a tap) will be a machine, while a complex automaton producing bottles or electric bulbs will be an instrument, since it hardly requires any operation.

Marx's definition of a machine draws attention to the fact that it caused a revolution in the very process of production.

The motive power is a necessary and very important component part of the machinery of industrial capitalism, but it does not determine its fundamental character. When John Wyatt invented his first spinning machine he did not even mention how it was driven. "A machine in order to spin without the aid of fingers" was his programme.[54]

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[53] Franz Reuleaux, *Theoretische Kinematik. Grundzüge einer Theorie des Maschinenwesens.* Braunschweig: Vieweg, 1875 p. 38. "Eine Maschine ist eine Verbindung widerstandsfähiger Körper, welche so eingerichtet ist, dass mittelst ihrer mechanische Naturkräfte genöthigt werden können, unter bestimmten Bewegungen zu wirken."

[54] Cf. *Capital* MEW 23, 392.

It was not the development of the motor and the invention of the steam engine that created the industrial revolution of the 18th century, but on the contrary the steam engine gained such enormous importance precisely because the division of labour that was emerging in manufacture and its increasing productivity made the invention of an accomplishing instrument, both possible and necessary, and the steam engine, which had been born in the mining industry, found a field awaiting its application as a motive power.

Arkwright's spinning jenny was at first driven by means of water. However the use of water power as the predominant form of motive power involved great difficulties.

It could not be raised to an arbitrary [random?] level; if there was a shortage of it, it could not be replenished; sometimes it dried up; and it always had a purely local character.

Only with the invention of Watt's machine did the machine textile industry, which was already fairly well developed, receive the motor that was essential for it at that particular stage of development.

Thus the machine textile industry is by no means a consequence of the invention of the steam engine.

The steam engine was born in the mining industry. As early as 1630 Ramsay was granted a patent in England "to raise water from low pits by fire."

In 1711 the Proprietors of the Invention for Raising Water by Fire was formed for exploiting Newcomen's engine in England.

The greatest service rendered by England's thermal (steam) engine, Carnot wrote in his work *On the Motive Power of Heat*, was undoubtedly the revival of the working of the coal mines, which threatened to cease entirely in consequence of the continually increasing difficulty of drainage and of raising the coal.[55]

The steam engine gradually became an important factor in production. It was then noticed that it could be made more economical by reducing the consumption of steam, and consequently the consumption of water and fuel.

Even before Watt's work Smeaton was investigating the consumption of steam in different steam engines, setting up a special laboratory for this purpose in 1769. He found that steam consumption in different engines varies from 176 to 76 kg. per horsepower hour. Savery succeeded in building an engine of the Newcomen type with a steam consumption of 60 kg. per horsepower hour.

By 1767 fifty-seven steam engines with a total power of 1,200 horsepower were already at work around Newcastle alone.

It is no wonder that the problem of economy was one of the main problems confronting Watt.

Watt's patent, taken out in 1769, begins thus: "My method of lessening the consumption of steam in fire engines, and thus the expenditure of combustible material, consists in the following basic propositions."

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[55]Sadi Carnot, *Réflexions sur la puissance motrice du feu:et sur les machines propres à développer cette puissance* (Paris: Bachelier, 1824) p. 3 "Le service le plus signalé que la machine à feu ait rendu à l'Angleterre est sans contredit d'avoir ranimé l'exploitation des ses mines de houille, devenue languissante et qui menaçait de s'eteindre entièrement à cause de la difficulté toujours croissante des épuisemens et de l'extraction du combustible."

Watt and Boulton concluded an agreement with an owner of coal mines, according to which they would be paid one-third of the sum saved by the reduced expenditure on fuel.

According to this agreement, they received over two thousand pounds [in Russian 45 thousand marks] a year from this mine alone.

The chief inventions of the textile industry were made in the period 1735–1780, thus creating an immediate demand for a motor.

In his patent taken out in 1784 Watt described the steam engine as the universal motor of large industry.

The main problem was the technical rationalization of the steam engine. In order to realize this task in practice it was necessary to make a detailed study of the physical processes that occurred in the engine.

Unlike Newcomen, Watt, in the laboratory of Glasgow University, made a detailed study of the thermo-dynamic properties of steam, thus laying the basis for thermodynamics as a section of physics.

He carried out a number of experiments on the temperature of boiling water under various pressures in relation to change in the expansibility of steam. Then he investigated the latent temperature of steam formation and developed and tested Black's theory.

Thus the main problems of thermo-dynamics, the teaching about the latent temperature of steam formation, the dependence of boiling point on pressure and the magnitude of the latent temperature of steam formation, began to be scientifically elaborated by Watt.

It was this detailed study of the physical processes in the steam engine that enabled Watt to go further than Smeaton, who, despite his goal of investigating the steam engine in the laboratory, was limited to making purely empirical, superficial improvements to Newcomen's engine, since he had no knowledge of the physical properties of water vapours.

Thermodynamics not only received an impetus to its development from the steam engine, but in fact developed from the study of that engine.

It became necessary to study not only the particular physical processes in the steam engine, but the general theory of steam engines, the general theory of the efficiency coefficient of steam engines. This work was carried out by Sadi Carnot.

The general theory of the steam engine and the theory of the efficiency coefficient led Carnot to the necessity of investigating general thermal processes, to the discovery of the second principle of thermodynamics.

The study of steam engines, said Carnot in his work *On the Motive Power of Heat* (1824), is of the greatest interest, as their importance is enormous and their use is continually increasing. Clearly they are destined to produce a great revolution in the civilized world.[56]

Carnot remarked that, despite various kinds of improvements, the theory of the steam engine had made but little progress.

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[56] Carnot 1824, p. 2. "L'étude de ces machines est du plus haut intérêt, leur importance est immense, leur emploi s'accroît tous les jours. Elles paraissent destinées à produire une grande révolution dans le monde civilisé."

Carnot formulated his task of discovering the theory of the steam engine in such a way that the practical problems he set in order to discover the general theory of the efficiency coefficient are quite clear.

The question has often been raised, he wrote, whether the motive power of heat is unbounded or infinite; by motive power we mean the effective activity a motive power can provide.

Is there any limit to the possible improvements, a limit that the nature of things will not allow to be passed by any means whatever? Or, on the contrary, can these improvements be carried on indefinitely?[57]

Machines which do not receive their motion from heat, but have for a motor the force of men, animals, a waterfall, an air current, can be studied, Carnot observed, by means of theoretical mechanics.

Here, all cases are foreseen, all imaginable movements are referred to their general principles (which was made possible by Newton's work on mechanics), firmly established and applicable in all circumstances.

No such theory exists in the case of heat engines.

We cannot have such a theory, Carnot stated, until the laws of physics are extended enough, generalized enough, to make known beforehand all the effects of heat acting in a determined manner on any body.[58]

Here the connection between technology and science, between the investigation of the general laws of physics and the technical problems raised by economic development is established with extraordinary clarity.

But the history of the steam engine is important to us in another connection as well.

Historically, the investigation of various forms of physical motion of matter took place in the following sequence: mechanics, heat, electricity.

We have seen that the development of industrial capitalism presented technology with the demand to create a universal motor.

This demand was preliminarily supplied by the steam engine, which had no competitors until the invention of the electric motor.

The problem of the theory of the efficiency coefficient of steam engines led to the development of thermodynamics, i.e., to the study of the thermal form of motion.

This, therefore, is the explanation for the historical sequence in the study of forms of motion: the study of the thermal form of motion—thermodynamics—developed in the wake of mechanics.

We shall now proceed to a consideration of the importance of the steam engine from the perspective of the transformation of one form of motion into another.

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[57]Carnot 1824, pp. 6-7: "L'on a souvent agité la question de savoir si la puissance motrice de la chaleur est limitée, ou si elle est sans bornes; si les perfectionnemens possibles des machines à feu ont un terme assignable, terme que la nature des choses empêche de dépasser par quelue moyen que ce soit, ou si au contraire ces perfectionnemens sont susceptibles d'une extension indéfinie."

[58]Carnot 1824, pp. 9-10 "On ne la possédera que lorsque les lois de la physique seront assez étendues, assez généralisées, pour faire connaître à l'avance tous les effets de la chaleur agissant d'une manière déterminée sur un corps quelconque."

Whilst Newton never even posed the problem of the law of the conservation and transformation of energy, Carnot was compelled to pose it, although still in an unclear form.

The reason for this was that Carnot's study of the steam engine focused precisely on the transformation of thermal into mechanical energy.

The category of energy as one of the basic categories of physics appeared at the time when the problem of the correlations between various forms of motion emerged. And as the forms of motion investigated by physics became more varied, so the category of energy acquired ever more significance.

Thus the historical development of the study of physical forms of motion of matter should provide the key to understanding the origin, significance and interconnection of the categories of physics.

A historical study of forms of motion should be conducted from two perspectives. We must study the historical sequence of the forms of motion as they appear in the development of the science of physics in human society. We have already shown the connection between the mechanical and the thermal form of motion from the perspective of their historical genesis in human society. The study of these forms follows the sequence in which they were brought to the forefront by human practice.

The second perspective is to study the "natural science of the development of matter." The process of studying the development of inorganic matter in the microcosmos and the macrocosmos should provide the key to understanding the connection between the various forms of motion of inorganic matter and the reciprocal transitions from one to another, and should lay a sound basis for a natural classification of forms of motion of matter. This principle should lie at the basis of the Marxist classification of sciences.

Every science analyses a single form of motion or a series of forms of motion that are interconnected and pass into one another.

The classification of sciences is none other than a hierarchy of the forms of motion of matter in accordance with their essential order, in other words, in accordance with their natural development and the passing of one form of motion into another, as they occur in nature.

Hence, this principle of a Marxist classification of science bases classification on the great idea of the development and the passing of one form of motion of matter into another form.[59]

Herein consists Engel's remarkable notion of the interconnection and hierarchy of forms of motion of matter.

The conception of energy is indissolubly bound up with the transformation of one form into another, with the problem of measuring this transformation. Modern physics emphasises precisely the quantitative aspect of this transformation and postulates the constancy of energy during those transformations.

We recall, as was shown in the previous chapter, that the constancy and invariability of quantity of motion were already stated by Descartes. The new element introduced into physics by the work of Mayer and Helmholtz lay in the discovery of the transformation of forms of motion along with the constancy of energy during these transformations.

It was this, and not the simple postulation of constancy, that was the new element.

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[59] Engels: *Dialectics of Nature*: MEW 20, 514.

As a result of this discovery, the different isolated forces of physics (heat, electricity, mechanical energy), which until then had been seen as comparable to the invariable species of biology, were transformed into interconnected forms of motion that pass into one another according to definite laws.

Like astronomy, physics came to the inevitable conclusion that the end result was the eternal circulation of moving matter. That is why Newton's period, which was acquainted with only one form of motion—the mechanical—and was primarily interested, not in the conversion of one form into another, but only in the transformation and modification of one and the same form of motion—mechanical change of place]—(let us recall Vitrivius's definition of a machine and Carnot's observations) did not, and could not, consider the problems of energy.

As soon as the thermal form of motion appeared on the scene, and precisely because it appeared on the scene when it was indissolubly bound up with the problem of its conversion into mechanical motion, the problem of energy came to the forefront. The very way in which the problem of the steam engine was formulated ("to raise water by fire") clearly points to its connection with the problem of the conversion of one form of motion into another. It is not by chance that Carnot's classic work is entitled: *On the Motive Power of Heat.*

Engels' treatment of the law of the conservation and conversion of energy emphasises the qualitative aspect of the law of conservation of energy, in contradistinction to the predominant treatment in contemporary physics that reduces it to a purely quantitative law—the quantitative constancy of energy during its transformations. The law of the conservation of energy, of the indestructibility of motion, should be understood not only in a quantitative but also in a qualitative sense. It contains not only the postulation that energy cannot be destroyed or created, which is one of the basic prerequisites of the materialistic conception of nature, but a dialectical treatment of the problem of the motion of matter. From the perspective of dialectical materialism, the indestructibility of motion consists not only in the fact that matter moves within the limits of one form of motion, but also in the fact that matter itself is capable of producing from itself all the endless variety of forms of motion in their spontaneous transformations into one another, in their self-movement and development.

We see that only the conception of Marx, Engels and Lenin provides the key to understanding the historical sequence of the development and investigation of forms of motion of matter.

If Newton did not consider or solve the problem of the conservation of energy, this, of course, was not because he lacked genius.

Great men in all spheres, no matter how remarkable their genius, formulate and resolve those problems that have been placed on the agenda by the historical development of the forces and relations of production in their time.

The Machine-Wreckers in Newton's Age and the Present-Day Wreckers of the Productive Forces.

We have come to the end of our analysis of the *Principia*. We have shown how its physical content arose out of the tasks of that era, which were placed on the agenda by the class that was coming to power.

The historically inevitable transition from feudalism to merchant capital and manufacture, and from manufacture to industrial capitalism, stimulated an unprecedented development of the productive forces, and this in turn gave a powerful impetus to the development of scientific research in all spheres of human knowledge.

Newton happened to live in the very age when new forms of social relations, new forms of production, were being created.

In his mechanics he was able to solve the complex of physical and technical problems placed on the agenda by the rising bourgeoisie.

But he came to a halt, helpless, before nature as a whole. Newton was familiar with the mechanical change of place of bodies, but he rejected the view that nature is in a process of unceasing development. Still less can we hope to find in him any view of society as a developing whole, even though it was change that characterized his era and gave rise to his main work.

Has the movement of the historical process ceased since Newton's time? Of course not, for nothing can check the forward movement of history.

After Newton, Kant and Laplace were the first to make a breach in the view of nature as eternal and unchanging throughout the ages. They showed, albeit in a far from complete form, that the solar system is the product of historical development.

It was through their works that the notion of development, which was subsequently to become the basic and guiding principle of all teaching on nature, entered into natural science for the first time.

The solar system was not created by God, the movement of the planets is not the result of a divine impulse. It not only preserves its state solely as a consequence of natural causes, but also came into existence through their influence alone. Not only does God have no place in a system whose existence is based on the laws of mechanics, but he is unnecessary even as an explanation of its origin.

"I have had no need to include any hypothesis of a deity in my system, Your Highness," so Laplace is said to have replied when Napoleon asked him why he had omitted all reference to the role of God in his *System of the World*.

The progressive development of the productive forces gave rise to progressive science.

The transition from domestic handicraft industry to manufacture and from manufacture to large-scale machine industry, which was only beginning in Newton's age, was greatly accelerated during the following century. It was completed by the monopolistic imperialist phase of capitalism, which was the threshold to new, socialist forms of development.

As one phase of the capitalist method of production was replaced by another, so the very views on technology and science held by the ruling class in capitalist society changed.

On coming to power the bourgeoisie struggled mercilessly against the old guild and handicraft modes of production. With an iron hand it introduced large-scale machine industry, shattering in its course the resistance of the obsolete feudal class and the still unorganized protest of the newborn proletariat.

Science and technology are powerful weapons of struggle for the bourgeoisie, and it is interested in developing and perfecting these weapons.

The bard of industrial capitalism of this period (Ure)[60] portrayed the struggle of the bourgeoisie for new methods of production in the following terms:

“Then the combined malcontents, who fancied themselves impregnably entrenched behind the old lines of division of labour, found their flanks turned and their defences rendered useless by the new mechanical tactics, and were obliged to surrender at discretion.”

Examining further the significance of the invention of the spinning machine, he said: “A creation destined to restore order among the industrious classes … This invention confirms the great doctrine already propounded, that when capital enlists science into her service, the refractory hand of labour will always be taught docility.”[61]

Ure spoke for the bourgeoisie that was coming to power as it built new methods of production on the blood and bones of the “refractory hand of labour.”

On coming to power the bourgeoisie revolutionised all modes of production. It tore the old feudal bonds to shreds and shattered the archaic forms of social relations that fettered the further development of the productive forces. In that period it was revolutionary because it brought with it new and more advanced methods of production.

Over a period of a century it changed the face of the earth and brought into existence new, powerful productive forces.

New, hitherto unexplored forms of motion of matter were discovered.

The immense development of technology was a powerful stimulus to the development of science, and the rapidly developing science in turn fertilized the new technology.

And this unprecedented flourishing of the productive forces, the tremendous growth of material culture, brought about the unprecedented impoverishment of the masses of the people and a terrible growth in unemployment.

It is not surprising that these contradictions in the predominant capitalist methods of production should have attracted the attention, not only of the state officials in the capitalist countries, but also of their scientists.

In Newton’s period the bourgeoisie called for new methods of production. In his memorandum on the reform of the Royal Society, Newton urged the state authorities to support science, which contributed so much to the study of nature and the creation of new productive forces.

Today the situation is very different.

In 1930/31 *Nature* published a number of leading articles dealing with the questions we are considering. These articles consider problems that are now agitating the whole world. Of these articles, we will consider two that express most clearly the point of view of English natural scientists. One is entitled “Unemployment and Hope,” the other “Science and Society.”

This is how these articles depict the tasks of industry, its aims and course of development.

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[60]Andrew Ure (1778–1857) English chemist and economist: “Dr. Ure, the Pindar of the automatic factory” Marx, *Capital* MEW 23, 441 (CW 35, 421).

[61]Ure, Andrew, *The Philosophy of Manufactures or an Exposition of the Scientific, Moral and Commercial Economy of the Factory System of Great Britain*, London, 1935 pp. 368-370, quoted in Capital MEW 23, 460 (CW 35, 439)

Discussing the question of unemployment, which is rending capitalist society, *Nature* defines the role of machines as follows:

"There is, indeed, in the present situation much to excuse a passing reflection that perhaps, after all, the people of Erewhon were wiser than ourselves in destroying their machines, lest, as Marx predicted, the machines reversed the original relation and the workmen became the tool and appendage of a lifeless mechanism."[62]

Modern science and technology create machines of remarkable precision and productivity, with an extraordinarily complex and delicate structure. And it now appears that the machine wreckers of Newton's period were wiser than we, who create machines of unprecedented complexity and power.

The above quotation not only distorts the ideas of Marx, but also misinterprets the movement of the machine-wreckers.

Let us first re-establish the true historic circumstances and actual reasons that drove the workers to wreck the machines.

The workers' struggle against the machine merely reflected the struggle between wage labourers and capitalists. The working class of that period did not struggle against the machines as such but against the position to which the developing capitalist order was relegating it in the new society.

During the 17th century the whole of Europe experienced the workers' anger against the carding machines. The first wind-power saw-mill was destroyed in London at the end of the 1670s.

The first decade of the 19th century was marked by the mass movement of the Luddites against the power loom. As industrial capitalism developed it transformed labour power into a commodity. Forced out of industry by machinery, the worker could not find a purchaser for his labour, and was comparable to paper money that had gone out of circulation. The growing working class, which had not yet developed a class consciousness, directed its hatred against the external forms of capitalist relations—the machines.

But this reactionary form of protest in fact expressed a revolutionary protest against the system of wage labour and private ownership of the means of production.

The worker was indeed becoming an appendage to the machine, not because machines had been invented, but because these machines served the interest of the class that owned the means of production.

The call to machine-wrecking will always be a reactionary slogan, and the wisdom of the inhabitants of Erewhon consisted not in their destroying the machines, but in their protest against the slavery of wage labour.

"The comfort and the welfare of the few," continues the leading article, "on this view, may, however, be too dearly purchased when we consider the lot of the displaced workers, and, perhaps, still more the repression of individuality and the retarded development which, as Marx predicted, have often accompanied mass production."

Thus, in the opinion of *Nature*, improvement in the means of production inevitably leads to the repression of individuality and the suffering of the masses of the people.

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[62]Following quotes corrected according to "Science and Society," *Nature 126,* No. 3179 Oct. 4, 1930, p. 497.

Here it is permissible to ask: Why was it that during Newton's time, when there was an enormous development in the means of production, scientific circles not only did not call for a curb on this development, but, on the contrary, made every effort to encourage every new discovery and invention; and the organ of the leading natural scientists in Newton's period, *Philosophical Transactions*, was full of descriptions of these new inventions?

Before answering this question we will see what methods this journal of British naturalists proposes for solving the crisis of production and unemployment, which, so it believes, are the results of the overdevelopment of the productive forces.

These methods are outlined in the leading article "Unemployment and Hope." We quote the corresponding section *in extenso*:[63]

"The aims of industry are, or should be, … chiefly two (1) to furnish a field for … growth of character; and (2) to produce commodities to satisfy man's varied wants, mostly of a material kind, though of course there are large exceptions outside the material category, and the term 'material' is here used in no derogatory sense. Attention has hitherto been directed mainly to (2) and the primary aim of industry has been ignored. Such one-sided view of industry coupled with a too narrow use of the much abused word 'evolution' … has, led to over-concentration on quantity and mass production and a ridiculous neglect of the human element and there can be no doubt that had a little thought been given to the first aim then the second would have been much more completely and satisfactorily attained; also unemployment would not have been heard of …

"The prevailing idea … appears to be that industry is evolving and must evolve towards one fixed type, for example, that of large-scale production…The best form or type of industry … may consist of many different and constantly changing forms, distinguished above all things by adaptability and elasticity—a living organism.

"Elasticity further means the possibility of reviving, under new and improved forms to meet modern conditions, two at least of the older types of industry which are supposed to have been superseded or rendered obsolete by modern large-scale production, namely: (1) small cottage industries or handicrafts…; (2) a combination of manufacturing with agricultural or garden industry… Industry still has its roots firmly and deeply fixed in the past, and foolishly to tear up a great part of those roots as old and useless is the surest way to weaken the industrial tree. Perchance the source of the unemployment curse is to be found here.

"The restitution of these two principles of an older industrial order, so essentially and characteristically English, under improved forms made possible by modern scientific achievement, including notably electrical power distribution, would furnish, in the first place, a new and almost infinite field for human employment of all kinds, absorbing all or most of the present unemployed… By unemployed we mean chiefly the unemployed in Great Britain only, but it would be vastly better to extend our consideration to cover unemployment throughout the whole world …

"The application of these two principles to unemployment is, of course, only one part of their scope, for they have a far wider range even than this, especially in counteracting one of the

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[63]Following quotes are corrected of minor errors according to W. G. Linn Cass, "Unemployment and Hope," *Nature 125,* No. 3146 Feb. 15, 1930, pp. 226-227.

greatest evils of modern industry, namely, extreme specialism, monotonous work, and lack of scope for developing skill, with all that that implies …

"It is probable that, under the more bracing atmosphere of varied work and interest and skill thus envisaged, the inventive faculties of mankind would be greatly stimulated, and a much needed spur be given to originality."

Thus, according to *Nature*, the remedy for healing the wounds of capitalist society, the means of eliminating all the contradictions of a system based on wage labour and individual ownership of the means of production, is a return to those forms of industry that directly preceded the age of industrial capitalism.

We have demonstrated above that it was these very forms that engendered the advances in Newton's period; and although they were a step forward by comparison with feudal methods of production, manufacture and small handicraft industry, at the present time the slogan "Back to small handicraft industry" is profoundly reactionary.

The fetishism of the commodity system, which Marx so brilliantly exposed, lies in the fact that the relations of material things created by human society are isolated from human relations and are considered as inherent to the things themselves.

This fetishism can be deciphered and exposed by understanding that it is not things as such that create relations, but that the relations between things created in the process of social production simply express a particular social relation between people, which they conceive of in the fantastical form of relations between things.

The views cited above are also a certain form of fetishism. Machinery, the means of production, the organisation of production into large-scale machine production are considered in isolation, outside the social relations of the particular economic system in which the given mode of production exists and by which it is created.

Improving the instruments of labour brings misfortune to the great mass of the population, we are told. The machine transforms the worker into its mere appendage. It kills individuality. Let us return to the good old days.

No, we reply. It is not the improvement in the means of production that causes the impoverishment and unprecedented sufferings of the masses. It is not the machines that transform the worker into a blind appendage of a mechanism, but those social relations that exploit machinery in such a way as to turn the worker into a mere appendage to it.

The solution lies not in returning to the old, long since obsolete modes of production, but in changing the entire system of social relations, a change that is just as radical as the transition from feudal and handicraft methods of production to industrial capitalism was in its time.

Private property passes through three stages of development: feudalism, merchant capital and manufacture, industrial capitalism.

At every stage of development in the process of production of their lives, people involuntarily enter into specific relations of production that correspond to the stage of development of the productive forces. At a certain stage of their development, the productive forces come into antagonism with the existing relations of production or, in juridical terms, with the property relations within which they developed. Having previously been their forms of development, the latter become their fetters.

The further development of productive forces is only possible through a radical reconstruction of all relations of production.

The transition from one form of production to another is characterised first and foremost by such a reconstruction.

At every new stage the change in social relations brings about a further rapid growth in the productive forces.

And, conversely, a crisis in the growth of the productive forces indicates that they are unable to continue to develop within the framework of the given social system.

The remedy that we cited above, which amounts to curbing the productive forces by a return to the old forms of production, is merely an expression of the contradiction between the productive forces in capitalist society and the relations of production based on private ownership of the means of production.

Science develops out of production, and those social forms that become fetters upon the productive forces likewise become fetters upon science.

Genuine methods for transforming society cannot be found through brilliant inspiration or guesswork, nor through a return to "the good old days" which in distant historical perspective appear to be a peaceful idyll, but which in reality were a bitter class struggle and the repression of one class by another.

Thus it has always been, and so it was in the age when Newton lived and worked, and to whose forms of production it is proposed that we return.

We have seen that the obsolete system of social relations of that period, speaking through their universities, also recommended restricting science, which was shattering the stagnant forms of feudal ideology and was entering into the service of a new mode of production.

What we are now witnessing is the repetition, on a new basis, of the fundamental antagonism between the forces and relations of production that Marx so brilliantly and lucidly revealed and explained.

Whilst the newly emerging proletariat spontaneously protested by wrecking machines and resisting inventions and science, today, armed with Marx's, Engels' and Lenin's method of dialectical materialism, the proletariat clearly sees the path towards the liberation of the world from exploitation of man by man.

The proletariat knows that genuine scientific knowledge of the laws of the historical process leads with iron necessity to the conclusion that the change from one social system to another is inevitable—to the change from capitalism to socialism.

The proletariat exposes all the fetishes of class society and sees, behind the relations between things, the relations between the human beings who create these things.

Having learnt the real nature of the historical process, the proletariat does not remain a mere spectator. It is not only the object, but the subject of the process.

The great historical significance of the method created by Marx lies in the fact that knowledge is not regarded as the passive, contemplative perception of reality, but as the means for actively reconstructing it.

For the proletariat science is a means and instrument for this reconstruction. That is why we are not afraid to expose the "terrestrial origin" of science, its close connection to the mode of production of material existence.

Only such a conception of science can truly liberate it from those fetters in which it is inevitably trapped in bourgeois class society.

Not only does the proletariat have no fear of the development of the productive forces, but it alone is capable of creating all the conditions for their unprecedented flourishing, and also for the flourishing of science.

The teachings of Marx and Lenin have been embodied in life. The socialist reconstruction of society is not a distant prospect, not an abstract theory, but a definite plan for the great works being accomplished by the population of one-sixth of the globe.

And as in all eras, by reconstructing social relations we reconstruct science.

The new method of research, which in the persons of Bacon, Descartes and Newton gained victory over scholasticism and led to the creation of a new science, was the result of the victory of the new mode of production over feudalism.

The building of socialism not only absorbs into itself all the achievements of human thought, but, by setting science new and hitherto unknown tasks, charts new paths for its development and enriches the storehouse of human knowledge with new treasures.

Only in socialist society will science genuinely belong to all mankind. New paths of development are opening up before it, and its victorious march has no bounds either in infinite space or in eternal time.