THE SOCIAL AND ECONOMIC ROOTS OF NEWTON'S 'PRINCIPIA.'

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INTRODUCTION :

MARX'S THEORY OF THE HISTORICAL PROCESS.

The work and also the personality of Newton have attracted the attention of scientists of all ages and nations. The enormous extent of his scientific discoveries, the significance of his work to all the later development of physics and technology, the notable exactitude of his laws justifiably arouse special respect for his genius.

What placed Newton at the turning-point of the development of science and gave him the possibility of indicating the new roads of this progressive movement ?

Where are we to seek the source of Newton's creative genius ? What determined the content and the direction of his activities ?

These are the questions which inevitably confront the investigator who takes as his task not the simple assembly of materials relating to Newton, but who wishes to penetrate into the very essence of his creative work.

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

Said Pope, in a well-known couplet.

Our new culture, declares Professor Whitehead, a famous British mathematician, in a recent book : " Science and Civilisation " owes its development to the fact that Newton was born in the very year of Galileo's death. Only think what the history of the development of humanity would have been if these two men had not appeared in the world.

The well-known English historian of Science, F .S. Marvin, a member of the presidium of this International Congress, associated himself with this view in his article : " The meaning of the 17th Century," which appeared a couple of months ago in " Nature."

Thus the phenomenon of Newton is regarded as due to the kindness of divine providence, and the mighty impulse which his work gave to the development of science and technology is regarded as the result of his personal genius.

In this lecture we present a radically different conception of Newton and his work.

The quotations made in this essay have been translated from Russian. The chief exceptions are the quotations from " Nature " in Chapter 5.

Our task will consist in applying the method of dialectical materialism and the conception of this historical process which Marx created to an analysis of the genesis and development of Newton's work in connection with the period in which he lived and worked.

We give a brief exposition of the basic assumptions put forward by Marx which will be the guiding assumptions of our lecture.

Marx expounded his history of the historical process in the preface to the " Critique of Political Economy " and in the " German Ideology." We shall attempt to give the essence of the Marxian viewpoint as far as possible in his own words.

Society exists and develops as an organic whole. In order to ensure that existence and development society must develop production. In social production people enter into definite inter-relationships which are independent of their own will. At every given stage these relationships correspond to the development of the material productive forces.

The aggregation of these productive forces forms the economic structure, the real basis on which the juridical and political superstructures are raised.

The definite forms of social consciousness also correspond to this basis.

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

It is not the consciousness of human beings which determines their existence, but on the contrary their social existence determines their consciousness. At a certain stage of its development the material productive forces of society come into antagonism with the existing production relationships, or with the property relationships within which they have hitherto developed (which is only a juridical expression of the same thing).

From being forms of productive forces they are transformed into fetters of those forces. Then follows the period of social revolutions. With the change of bases there occurs a transformation in all the enormous super-structure also.

The prevailing consciousness during these periods has to be explained by reference to the antagonisms of material existence, to the existing conflict between the productive forces and the production relationships.

Lenin remarks that this conception of the materialistic interpretation of history eliminates two chief defects of the previous historical theories.

Previous historical theories considered only the intellectual motives of the historical activity of people as such. Consequently they could not reveal the true roots of those motives, and consequently history was justified by the individual intellectual impulses of human beings. Thus the road was closed to any 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. Personality was the creator of history.

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

The second defect which Marx's theory eliminates is that the subject of history is not the mass of the population, but the personalities of genius. The most obvious representative of this view is Carlyle, for whom history was the story of great men.

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 force of genius transforms those conditions, itself not being in need of any extrinsic material factors.

In contradistinction to this view Marx observes the movement of the history-making masses and studies the social conditions of the life of the masses and the modifications in those conditions.

Marxism, as Lenin emphasises, pointed the way to an all-embracing study of the process of origination, development and decline of social systems. It explains this process by considering all the aggregation of contradictory tendencies, reducing them to the exactly determined conditions of existence and the production of the various classes.

Marxism eliminates subjectivism and arbitrariness in the selection of the various " dominating " ideas or in their interpretation, attributing the roots of all ideas without exception, to the state of the material productive forces.

In class society the ruling class subjects the productive forces to itself and, by virtue of its domination of material force subjects all other classes to its interests.

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

In capitalist society a separation of the dominating ideas from the production relationships occurs, and thus is created the view that the material structure is determined by ideas.

Practice has not to be explained by reference to ideas, but on the contrary the formation of ideas has to be explained by reference to material practice.

Only the proletariat, which has as its objective the creation of the classless society, is freed of limitations to its conception of the historical process and creates a true, genuine history of nature and of society.

The period during which Newton's activity was at its height corresponds with the period of the English Civil War and Commonwealth.

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

THE ECONOMICS, PHYSICS AND TECHNOLOGY OF NEWTON'S PERIOD.

The general symptom of that section of world history which has come to be known as mediæval and modern history is first and foremost that during this period we have the rule of private property.

All the social and economic formations of this period preserve this basic symptom.

Consequently Marx regarded this period of the history of humanity as the history of the development of forms of private property, and distinguishes three subsidiary periods within the larger epoch.

The first period is that of the rule 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 the rule of industrial capitalism. It gives birth to large-scale industry, the application of the forces of nature to industrial purposes, mechanisation and the most detailed division of labour.

The brilliant successes of natural science during the sixteenth and seventeenth centuries were conditioned by the disintegration of the feudal economy, the development of merchant capital, of international maritime relationships and of heavy (mining) industry.

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

Production for the purpose of exchange was only then emerging. Hence the limited nature of exchange and of the market, the self-centred and static forms of production, the local isolation from the external world, the purely local connections of 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.

In the mediæval towns there was no division of labour among the various crafts nor within those crafts among the various workers.

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

The next step in the realm of the division of labour was the separation of production from the forms of intercourse and the formation of a special class of merchants.

The bounds of commerce were widened. Towns entered into relationships with one another. There arose the necessity for the roads to be publicly safe, and the demand for good roads of communications and means of transport.

The newly developing associations between towns led to the distribution of production among them. Each developed a special sphere of production.

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

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

Together with manufacture the relationships between the worker and the employer are modified. The monetary relationship between the capitalist and the worker makes its appearance.

Finally, the patriarchal relationships between the masters and the foremen are shattered.

Trade and manufacture created the great bourgeoisie. The petty bourgeoisie were concentrated in trades and were compelled in the towns to yield to the hegemony of the merchants and the manufacturers.

This period dates from the middle of the seventeenth century and continues to the end of the eighteenth.

Such is the 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 investigate first and foremost the historical demands imposed by the emergence of merchant capital and of its development.

Then we consider what technical problems the newly developing economy raised for solution and we investigate to what grouping of physical problems and of science necessary to the solution of those problems these technical problems led.

We direct our survey to three outstanding spheres which were of decisive importance to the social and economic system we are investigating. These spheres are ways and means of communication, industry, and military affairs.

Ways of Communication.

By the beginning of the middle ages trade had already achieved considerable development. Nevertheless, the land ways of communication were in a very miserable state. The roads were so narrow that even two horses could not pass. The ideal road was one on which three horses could travel side-by-side, where, in the expression of the time (14th century) " A bride could ride by without touching the funeral cart."

Commonly, commodities were carried in packs. Road construction was almost non-existent. The self-centred nature of feudal economy gave no impulse whatever to the development of 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 right of ownership to anything which fell on to their land from the cart or pack.

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

Naturally maritime and water transport played a great part, both in consequence of the great load-capacity of the vessels and also of the greater speed of transit: the largest of two-wheeled carts drawn by ten to twelve oxen hardly carried two tons of goods, whereas an average sized vessel carried upwards of 600 tons. During the fourteenth century the journey from Constantinople to Venice took three times as long by land as by sea.

Nevertheless even the sea transport of this period was very imperfect: as sound methods of establishing the ship's position in the open sea had not yet been invented, they sailed close to the shores, which greatly retarded the speed of transit.

Althqugh the first mention of the mariner's compass in the Arabian book " The Merchant's Treasury " dates to 1242. it came into universal use not earlier than the second half of the sixteenth century. Geographical maritime maps made their appearance about the same time.

But the compass and charts can be rationally exploited only when there is knowledge of methods of establishing the ship's position, i.e., when the latitude and longitude can be determined.

The development of merchant capital broke down the isolation of the town and the village commune, extended the geographical horizon to an extraordinary extent, and considerably accelerated the tempo of existence. It had need of convenient ways of communication, more perfect means of communication, a more exact measurement of time, especially in connection with the continually accelerating rate of exchange, and exact application of accounting and measuring.

Particular attention was directed to water transport: to maritime transport as a means of linking up various countries and to river transport as an internal link.

The development of river transport was also assisted by the fact that in antiquity waterways were the most convenient and most investigated, and the natural growth of the towns was linked up with the system of river communications. Transport over the rivers was three times as cheap as haulage transport.

The construction of canals also developed as a complementary means of internal transport and in order to link up the maritime transport with the internal river system.

Thus the development of merchant capital set transport the following technical problems:—

In the realm of water transport.

1. An increase in the tonnage capacity of vessels and in their speed.

2. An improvement in the vessels' floating qualities: their reliability, sea-worthiness, their lesser tendency to rock, response to direction and ease of manœuvring, which was especially important for war-vessels.

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

4. The perfecting of the internal waterways and their linking up with the sea; the construction of canals and locks.

Let us consider what physical prerequisites are necessary in order to resolve 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 liquids, 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 floating qualities of a vessel it is necessary to know the laws governing the movement of bodies in liquids—this is an aspect of the laws governing the

movement of bodies in a resistant medium—one of the basic tasks of hydrodynamics.

The problem of a vessel's stability when rocking is one of the basic tasks of the mechanics of material points.

The problem of determining the 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 of their movement—of the mechanics of the heavens.

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 thirties of the eighteenth century after the work of Huygens, in order to determine the longitude recourse was made to measurement of the distance between the moon and the fixed stars.

This method, put forward in 1498 by Amerigo Vespucci, demands an exact knowledge of the anomalies in the moon's movement and constitutes one of the most complicated tasks of the mechanics of the heavens. The determination of the times of the tides in dependence on the locality and on the position of the moon demands a knowledge of the theory of attraction, which also is a task of mechanics.

How important this task was is evident from the circumstance that long before Newton gave the world his general theory of tides on the basis of the theory of gravity, in 1590, Stevin drew up tables in which was shown the time of the tides in any given place in dependence on 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 liquids, since it is necessary to know how to estimate the pressure of water and the speed of its efflux. In 1598 Stevin was occupied with the problem of the pressure of water and he saw that water could exert a pressure on the bottom of a vessel greater than its weight; in 1642 Castelli published a special treatise on the movement of water in canals of various sections. In 1646 Torricelli was working on the theory of efflux of fluids.

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

Industry.

Already by the end of the middle ages (14th and 15th centuries) the mining industry was developing into a large industry. The mining of gold and silver in connection with the development of currency circulation was stimulated by the growth of exchange. The discovery of America was chiefly due to the gold famine, since European industry, which had developed so powerfully during the 14th and 15th centuries, and correspondingly European commerce, demanded larger supplies of the means of exchange; on the other hand the need for gold forced especial attention to be turned to the exploitation of mines and other sources of gold and silver.

The powerful development of the war industry, which had made enormous advances from the time of the invention of firearms and the introduction of heavy artillery, stimulated the exploitation of iron and copper mines to a tremendous extent. By 1350 firearms had become the customary weapon of the armies of eastern, southern and central Europe.

In the fifteenth century heavy artillery had reached a high level of perfection. 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 an aggregate weight of 2,230 tons, with 117,000 balls and 5,000 hand bombs in addition.

Consequently it is clear why the problem of the most effective exploitation of mines became a matter of prime importance.

First and foremost arises the problem set by the depth at which the ores lie. But the deeper the mines, the more difficult and dangerous work in them becomes.

A quantity of equipment for the pumping of water, the ventilation of the mines, and the raising of the ore to the surface becomes necessary. In addition a knowledge of the sound opening up of mines and of the plan of their workings is necessary.

By the beginning of the 16th century mining had reached a considerable development. Agricola left a detailed encyclopædia of mining from which one can see how much technical equipment had come to be applied in mining.

In order to raise the ore and to pump out water pumps and lifting equipment (windlasses and horizontal worms) were constructed; the energy of animals, the wind and falling water were all put into service. A complete pumping system began to exist, since with the deepening of the mines the problem of removing the water becomes one of the most important of the technical tasks.

In his book Agricola describes three kinds of instruments for drawing away water, seven kinds of pumps, and six kinds of equipment for drawing off water by ladling or bucketing, altogether sixteen kinds of water-raising machines.

The development of mining involved enormous equipment for the working up of the ore. Here we meet with

smelting furnaces, stamping mills, and machinery for dividing metals.

By the 16th century the mining industry had become a complex organism demanding considerable knowledge in its organisation and direction. Consequently the mining industry at once develops as a large-scale industry, free of the craft system, and so not subject to craft stagnation. It was technically the most progressive and engendered the most revolutionary elements of the working class during the middle ages, i.e., the miners.

The cutting 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 set the mining industry the following technical problems:—

1. The raising of ores from considerable depths.

2. Methods of ventilating the mines.

3. The pumping out of water and water-conducting equipment, the problem of the pump.

4. The transfer from the crude, damp-blast method of production predominant until the 15th century, to the more perfect form of blast-furnace production, in which the problem of air-blast equipment is raised, as it is in ventilation also.

5. The working up of the ores with the aid of rolling and cutting machinery.

Let us consider the problems of physics lying at the bases of these technical tasks.

1. The raising of ore and the task of equipping the raising machinery is a matter of arrangement of windlasses and blocks, i.e., of a variety of 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 task of statics.

3. The pumping of water from the mines and the equipment of pumps, especially of piston pumps, necessitates considerable investigation in the realm of hydro- and aerostatics.

Consequently Torricelli, Herique, and Pascal occupied themselves with the problem of raising liquids in tubes and with atmospheric pressure.

4. The transfer to the blast-furnace production at once evoked the phenomenon of great blast-furnaces with the necessary buildings, water-wheels, bellows, rolling machines and heavy hammers.

The problems of hydrostatics and dynamics set by the erection of water-wheels, the problem of air-bellows as also that of forced air for ventilation purposes also demand a study of the movement of air and its compression.

5. As in the case of other equipment, the construction of presses and heavy hammers brought into motion by utilising the force of falling water (or animal power) demands a complicated planning of cogged wheels and transmission mechanism, which also is essentially a task of mechanics. In the mill develops the science of friction and the mathematical arrangement of cogged transmission wheels.

Thus, leaving out of account the great demands which the mining and metal-working industries of this period made on chemistry, all the aggregate of tasks of physics fell within the limits of mechanics.

War and War Industry.

The history of war, Marx wrote to Engels in 1857, allows us more and more clearly to confirm the accuracy of our views on the connections between productive forces and social relationships.

Altogether the army is very important to economic development. It was in warfare that the craft order of corporations of artisans first originated. Here also we first find the application of machinery on a large scale.

Even the special value of metals and their role as currency were evidently based on their war significance.

So also the division of labour within various spheres of industry was first introduced in the army. Here in a tabloid form we find the entire history of the bourgeois system.

From the time of the application of gunpowder in Europe (it was used in China even before our era), a swift increase of firearms sets in.

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.

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

Nevertheless firearms were used not only in sieges, but 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 solidly from iron and copper. Gun-carriages were improved and transport made great strides forward. The rate of fire was accelerated. To this factor is due the success of Charles VIII. in Italy.

In the battle of Fornovo 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 means of resisting artillery by the artificial disposition of infantry and cavalry.

But of course the Italians were not satisfied with this alone, and they developed their own war industry. In Galileo's time the Arsenal at Florence had attained to considerable development.

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

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 shot and established that the angle of 45 degrees allows the greatest distance to flight. He also drew up tables for directing aim.

Vanucci 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 gave a certain standard in the production of guns and opened the way for the introduction of fixed theoretical principles and empirical laws of firing.

In 1690 the first artillery school was opened in France.

In 1697 San-Remi published the first complete primer of artillery.

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

Consequently experiments on the inter-relationship of calibre and charge, the relationship of calibre to weight and length of barrel, on the phenomenon of recoil, developed on a large scale.

The progress of ballistics went hand in hand with the work of the most prominent of the physicists.

Galileo gave the world the theory of the parabolic trajectory of a ball; Torricelli, Newton, Bernouilli and Enler engaged in the investigation of the flight of a ball through the air, studied the resistance of the air and the causes of declination.

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

The new form of defensive works (earthwork, fortresses) almost paralysed the activity of artillery in the middle of the 17th century, and this in turn gave a mighty impulse to its further development.

The development of the art of war raised the following technical problems:—

Intrinsic ballistics.

1. Study of the processes which occur in a firearm when fired and their improvement.
2. The stability combined with least weight of the firearm.
3. Adaptation to suitable and good aim.

Extrinsic ballistics.

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

The physical bases of these problems.

1. Study of the processes which occur in the firearm demands study of the compression and extension of gases —in its basis a task of mechanics, and also study of the phenomenon of recoil (the law of action and counter-action).

2. The stability of a firearm raises the problem of studying the resistance of materials and of testing their durability. This problem, which also has great importance for the art of construction in the given stage of development, is resolved by purely mechanical means. Galileo gives considerable attention to the problem in his " Mathematical Demonstrations."

3. The problem of a ball's trajectory through a vacuum consists in resolving the task of the free fall of a body under the influence of gravity and the conjuncture of its progressive movement with its free fall. Naturally therefore Galileo gave much attention to the problem of the free fall of bodies. How far his work was connected with the interests of the artillery and ballistics can be judged if only from the fact that he begins his " Mathematical Demonstrations " with an address to the Florentines, in which he praises the activity of the arsenal at Florence and points out that the work of this arsenal provides a rich material for the scientific study.

4. The flight of a ball through the air is part of the problem of the movement of bodies through a resistant medium and of the dependence of that resistance upon the speed of the movement.

5. The deviation of the ball from the estimated trajectory can occur in consequence of a change in the initial speed of the ball, a change in the density of the atmosphere, or through 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 ball's trajectory through a resistant medium is given.

Thus we see that if the process of the actual production of the firearm and the ball, which is a problem of metallurgy, be left out of account, the chief problems raised by the artillery of this period were problems of mechanics.

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

First and foremost we have to note that all of them are purely problems of mechanics.

We analyse in a very general way the basic themes of research in physics during the period in which merchant capital was becoming the predominant economic force and manufacture began to develop, 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 subjected to a special analysis. A comparison of the basic themes of physics enables us to determine the basic tendency of the interests of physics during the period immediately preceding Newton and contemporary with him.

1. The problem of simple machines, sloping surfaces and general problems of statics were studied by: Leonarda de Vinci (end of 16th century); Ubaldi (1577); Galileo (1589-1609); Cardan (middle of 16th century); and Stevin (1587).

2. The free fall of bodies and the trajectory of thrown bodies were studied by: Tartaglia (thirties of the 16th century); Benedetti (1587); Piccolomini (1598); Galileo (1589-1609); Riccioli (1652); The Academy del Cimente (1649).

3. The laws of hydro- and aerostatics, and atmospheric pressure. The pump, the movement of bodies through a resistant medium: Stevin, at the end of the 16th and beginning of the 17th centuries, the engineer and inspector of the land and water equipment of Holland; Galileo, Torricelli (first quarter of 17th century); Pascal (1647-1653); Herique (1650-1663), engineer to the army of Gustavus Adolphus, the builder of bridges and canals. Robert Boyle (seventies of the seventeenth century). Academy del Cimente (1657-1673).

4. Problems of the mechanics of the heavens, the theory of tides. Kepler (1609) ; Galileo (1609-1616) ; Hassendi (1647); Wren (sixties of 17th century); Halley (seventies of 17th century); Robert Hooke.

The above specified problems embrace almost the whole sphere of physics.

If we compare this basic series of themes with the physical problems which we found when analysing the technical demands of transport, means of communication, industry and war, it becomes quite clear that these problems of physics were fundamentally determined by these demands.

In fact the group of problems stated in the first paragraph constitute the physical problems relating to raising equipment and transmission mechanism important to the mining industry and the building art.

The second group of problems has fundamental significance for artillery and constitute the basic physical tasks of ballistics.

The third group of problems is of fundamental importance to the problems of pumping water from mines and of their ventilation, the smelting of ores, the building of canals and locks, intrinsic ballistics and calculating the form of vessels.

The fourth group is of enormous importance to navigation.

All these are fundamentally mechanical problems. This of course does not mean that during this period other aspects of the movement of matter did not occupy attention. During this period optics began to develop and the first observations on static electricity and magnetism were made. (1). Nevertheless both by their nature and by their specific importance these problems have quite a subsidiary significance, and by the extent of their investigation and mathematical development (with the exception of certain laws of geometrical optics, which were of considerable importance in the construction of optical instruments) lagged far behind mechanics.

1. Investigations into magnetism developed under the direct influence of the study of the deviation of the compass in the world's magnetic field, which had first been met with during the first distant sea expeditions. Gilbert gave much attention to the problems of the earth's magnetism.

So far as optics were concerned this science received its main impulse from those technical problems which were of importance first and foremost to marine navigation. (1).

1. During this period optics developed through study of the problem of the telescope.

We have compared the main technical and physical problems of the period with the scheme of investigations

govern physics during the period we are investigating, and we come to the conclusion that the scheme of physics was mainly determined by the economic and technical tasks which the rising bourgeoisie raised to the forefront.

During the period of merchant capital the development of productive forces set science with a series of practical tasks and made an imperative demand for their accomplishment.

Official science, the centres of which were the mediæval universities, not only made no attempt to accomplish these tasks, but actively opposed the development of natural sciences.

The universities of the fifteenth to the seventeenth centuries were the scientific centres of feudalism. They were not only the centres of feudal traditions but the active defenders of those traditions.

In 1655 during the struggle of the craft masters with the workers the Sorbonne actively defended the masters and the craft system, supporting the masters with " proofs from science and holy writ."

The entire system of pedagogy in the mediæval universities constituted a closed system of scholastics. There was no place for natural science in these universities. In Paris in 1355 it was decided to teach Euclid only on holidays.

The chief " natural-science " manuals were Aristotle's books, from which all the vital content had been removed. Even medicine was taught as a logical science. Nobody was allowed to study medicine unless he had studied logic for three years previously. It is true that when sitting for the medical examination the student had to face a question of a non-logical character, (testimony to his being the child of a lawful marriage) but obviously this one illogical question was hardly sufficient for a knowledge of medicine, and the famous chirurgian Arnold Villeneuve of Montpellier complained that even the professors in the medical faculty were not only unable to cure sufferers from the most ordinary of illnesses, but even unable to apply a leech.

The feudal universities struggled against the new science with a strength equal to that exerted by the dying feudal relationships against the new progressive methods of production.

Whatever was not to be found in Aristotle for them simply did not exist.

When Kircher (the beginning of the 17th century) suggested to a certain provincial Jesuit professor that he should gaze through the telescope at the newly discovered sun-spots, the latter replied: " It is useless, my son. I have read Aristotle through twice and have not found anything about spots on the sun in him. There are no spots on the sun. They arise either from the imperfections of your telescope or from the defects of your own eyes."

When Galileo invented the telescope and discovered the phases of Venus, whilst the merchant companies turned to him for his telescope, which was superior to those made in Holland, the scholastic university philosophers refused to hear about these new facts.

" We must smile, Kepler," Galileo wrote bitterly on August 19th, 1610, " at the great stupidity of men. What are you to say of the first philosophers of the school here, who with the stubbornness of an adder, despite invitations a thousand times repeated, did not wish even to glance either at the planets or at the moon, or even at the telescope itself. Truly the eyes of these men are closed to the light of truth. It is astounding, yet it does not surprise me. This kind of person thinks that philosophy is a kind of book .... that truth has to be sought not in the world, not in nature, but in the collation of texts."

When Descartes resolutely declared himself against Aristotelian physics and against University scholastics he met with savage opposition from Rome and the Sorbonne.

In 1671 the theologians and medicos of the Paris University demanded a governmental decision condemning Descartes' teaching.

In a biting satire Buoialeau ridiculed these demands of the learned scholastics. This notable document excellently describes the position of affairs in the mediæval universities.

Even in the second half of the 18th century the Jesuit professors in France could not reconcile themselves to Copernicus' theories. In 1760 in the latin translation of Newton's " Principia " Lesser and Jacquier thought it necessary to add the following note: " In his third book Newton applies the hypothesis of the movement of the earth. The author's assumptions cannot be explained except on the basis of this hypothesis. Thus we are compelled to act in another's name. But we ourselves openly declare that we accept the decisions published by the heads of the church against the movement of the earth."

The universities prepared almost exclusively ecclesiastics ?.nd jurists.

The church was the international centre of feudalism and itself was a large feudal proprietor, as not less than one third of the land in Catholic countries belonged to it.

The mediaeval universities were a powerful weapon of church hegemony.

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

The end of the middle-ages, (the middle of the 15th century) is characterised by a higher degree of development of the industry created by the mediæval burghers.

Production now became more perfect, various, and on a larger, a mass scale. Commercial relationships were more developed.

When, remarks Engels, after the dark night of the middle ages science again began to develop at a marvellous speed, industry was responsible.

From the time of the crusades industry 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 study, but also new means of experimentation and allowed of the construction of new instruments.

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

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

Finally, during this period appeared that mighty instrument of the distribution of knowledge: the printing press.

The construction of canals, locks and ships, the construction of shafts and working of mines, their ventilation, the pumping out of water from them, the planning and construction of firearms and fortresses, the problems of ballistics, the production and planning of instruments for navigation, the working out of methods of establishing courses at sea,—all demanded workers of a totally different type from those then being produced by the universities.

By the third quarter of the 16th century, when specifying the minimum of knowledge required by a mine-surveyor, Johann Matesius pointed out that he must have a thorough knowledge of the method of triangulation, must know Euclidian geometry well, must be able to use the compass, necessary in constructing galleries, must be able to calculate the correct direction of the mine, and must understand the construction of pumping and ventilation apparatus.

He pointed out that in order to construct galleries and work the mines theoretically educated engineers were required, since this work was far beyond the powers of an ordinary, uneducated miner.

In view of this it was obviously not possible to learn the profession in the universities of the time. The new science grew up in struggles with the universities, as a non-university science.

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

Science flourished step by step with the development and flourishing of the bourgeoisie. In order to develop its industry the bourgeoisie needed science, which would investigate the qualities of material bodies and the forms of manifestation of the forces of nature.

Hitherto science had been the humble servant of the church, and it was not allowed to pass beyond the bounds established by the church.

The bourgeoisie had need of science and science arose together with the bourgeoisie despite the church. (Engels.)

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 centres of the new science, of the new natural sciences were the scientific societies outside the universities.

In the fifties of the 17th century the famous Florentine Academia del Cimente was founded, taking as its function the study of nature by means of experiment. Among its membership were such scientists as Borelli and Viviani. The Academy was the intellectual heir of Galileo and Torricelli and continued their work. Its motto was *Provare e riprovore.*

In 1645 a circle of natural scientists was formed in London; they gathered weekly to discuss scientific problems and new discoveries, and from this gathering developed the Royal Society in 1661. The Royal Society brought together the leading and most eminent of the scientists in England, and in opposition to the university scholasticism adopted as its motto: 'Nullius in verba.' Active part in the society was taken by Robert Boyle, Bruncker, Brewster, Wren, Halley, and Robert Hooke. One of its most outstanding members was Newton.

We see that the rising bourgeoisie brought natural science into its service, the service of developing productive forces. At that time the most progressive class, it demanded the most progressive science. The English revolution gave a mighty stimulus to the development of productive forces. The necessity arose of not merely empirically resolving isolated

problems, but of synthetically surveying and laying a stable theoretical basis for the solution by general methods of all the aggregate of physical problems, set for immediate solution by the development of the new technique.

And since (as we have already demonstrated) the basic complex of problems was that of mechanics (1) this encyclopaedic survey of the physical problems was equivalent to the creation of a harmonious structure of theoretical mechanics which would supply general methods of resolving the tasks of the mechanics of earth and sky.

1. Optics also began to develop during this period, but the basic investigations in optics were subordinated to the interests of maritime navigation and to astronomy. It is important to note that Newton came to the study of the spectrum by way of the phenomenon of the chromatic abberration in the telescope.

The explanation of this work fell to Newton to supply. The very name of his most important work indicates that Newton set himself this particular synthetic task.

In his introduction to the " Principia " Newton points out that applied mechanics and instruction on simple machinery had been worked out previously and that his task consisted not in " discussing the various *crafts* and in resolving sectional tasks, but in giving instruction on nature, the mathematical bases of physics.

Newton's 'Principia' are expounded in abstract mathematical language and we should seek in them in vain for an exposition by Newton himself of the connection between the problems which he sets and solves with the technical demands out of which they arose.

Just as the geometrical method of exposition was not the method by means of which Newton made his discoveries, but, in his opinion, was to serve as a worthy vestment for the solutions found by other means, so in a work treating of 'Natural philosophy' we cannot expect to find references to the 'low' source of its inspiration.

We shall attempt to show that the 'earthy core" of the 'Principia' consists of just those technical problems which we have analysed above and which fundamentally determined the themes of physical research of the period.

Despite the abstract mathematical character of exposition adopted in the 'Principia' Newton was not only not a learned scholastic divorced from life, but in the full sense of the word was in 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 conception of his wide technical interests. The letter was written in 1669 after he had received his professor-ship, just as he was finishing the first outline of his theory of gravity.

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

Briefly summarised, Newton's instructions were: diligently to study the mechanism of steering and the methods of navigating ships; attentively to survey all the fortresses he should happen to find, their method of construction, their powers of resistance, their advantages in defence, and in general to acquaint himself with war organisation. To study the natural riches of the country, especially the metals and minerals, and also to acquaint himself with the methods of their production and purification. To study the methods of obtaining metals from ores. To discover whether it was a fact that in Hungary, Slovakia and Bohemia close to the town of Eila or in the Bohemian mountains not far from Silesia there was a river with waters containing gold, also to ascertain whether the methods of obtaining gold from gold-bearing rivers by amalgamating with mercury remained a secret, or whether it was now generally known. In Holland a factory for polishing glass had recently been established; he must go to see it. He must learn how the Dutch protected their vessels from rot during their voyages to India. He must discover whether pendulum clocks were of any use in determining longitude during distant ocean expeditions. The methods of transforming one metal into another, iron into copper for instance, or of any metal into mercury, were especially worth attention and study. In Chemnitz and in Hungary, where there were gold and silver mines, it was said they knew how to transform 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 not possible to obtain it. It was possible that they preferred to exploit it themselves in order to turn iron into copper to sell it.

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

That is not surprising. Newton's period was still very rich in alchemic investigations. The alchemists are commonly represented as a kind of magician seeking the philosopher's stone. In reality alchemy was closely bound up with production necessities and the mystery with which the alchemists were surrounded should not conceal from us the real nature of their researches.

The transformation of metals constituted an important technical problem, since the copper mines of the time were very few, and the war business and the casting of cannon demanded much copper.

The developing commerce made great demands on the means of circulation, and the European gold mines could not cover these demands. Together with the drive to the east in search of gold there was an intensification of the search for means of transforming the common metals into copper and gold.

From his youth Newton had always been interested in metallurgical processes, and he later successfully applied his knowledge and practice in his work at the Mint. He attentively studied the classics of alchemy and made considerable extracts which show his great interest in any and every form of metallurgical process.

During the period immediately preceding his work at the Mint, from 1683 to 1689, he gave much study to Agricola's works on metals, and the transformation of metals was his chief interest.

Newton, Boyle and Locke carried on extensive correspondence on the question of transforming metals and exchanged formulae for the transformation of ore into gold. In 1692 Boyle, who had been one of the directors of the East Indian Company, communicated his formula for transforming metal into gold to Newton.

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 of importance to note that whilst a rich material has been preserved relating to Newton's purely scientific activities, no material whatever has been preserved relating to his activities in the technical sphere. Not even the materials which would indicate Newton's activities at the Mint have been saved, although it is well-known that he did much to perfect the processes of casting and stamping money.

In connection with Newton's bi-centenary Jubilee, Laymann Newell, who especially studied the question of Newton's technical activities in the Mint, requested the director of the Mint, Captain Johnson, for materials touching on Newton's activities in the sphere of the technical processes of casting and stamping. In his reply Captain Johnson said that no materials whatever on this side of Newton's work had been preserved. All that is known is his extensive memorandum to the Chancellor of the Exchequer (1717) on the question of a bio-metallic system and the comparative value of gold and silver in various countries. This memorandum shows that Newton's circle of interests was not restricted to the technical questions of money-production, but extended to the economic problems of currency circulation.

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

We cite all these facts in opposition to the tradition which has been built up in literature, which represents Newton as an Olympian standing high above all the ' earthly ' technical and economic interests of his time, and soaring only in the empyraean of abstract thought.

It has to be said, as I have already observed, that the ' Principia ' certainly afford justification for such a treatment of Newton, which however, as we see, is absolutely opposed to the reality.

If we compare the circle of interests which was briefly outlined above, we have no difficulty in noting that it embraces almost entirely all that group of problems which arose from the interests of transport, commerce, industry and military affairs during his period, which we summarised on pages 7 and 15.

Now let us turn to an analysis of the contents of Newton's ' Principia ' and consider in what inter-relationships they stand with the themes of physical research of the period.

In the definitions and axioms or laws of motion are expounded the theoretical and methodological bases of mechanics.

In the first book is a detailed exposition of the general laws of motion under the influence of central forces. In this way Newton provides a preliminary completion of the work to establish the general principles of mechanics which Galileo had begun.

Newton's laws provide a general method for the resolution of the great majority of mechanical tasks.

The second book, devoted to the problem of the movement of bodies, treats of a number of problems connected with the complex of problems which we have already noted.

The first three sections of the second book are devoted to the problem of the movement of bodies in a resistant medium in relation to various cases of the dependence of resistance upon speed (lineal resistance, resistance proportional to the second degree of speed and resistance proportional to part of the first part of the second degree).

As we have above shown when analysing the physical problems of ballistics, the development of which was con-

nected with the development of heavy artillery, the tasks set and accomplished 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 set by the construction of vessels, canals, water-pumping and ventilating equipment, we saw that the physical themes of these problems relate to the fundamentals of hydrostatics and aerostatics.

The sixth section deals with the problem of the movement of pendulums against resistance.

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

We have seen from Newton's letter to Aston of what importance were pendulum clocks in determining longitude. The application of clocks in determining longitude led Huygens to the discovery of centrifugal force and the changes in acceleration of the force of gravity.

When the pendulum clocks brought by Riche from Paris to Caen in 1673 displayed a retarded movement Huygens was able at once to explain the phenomenon by the changes in acceleration of the force of gravity. The importance attached by Huygens himself 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 passed from the mathematical case of the movement of bodies in a resistant medium with lineal resistance to the study of an actual case of movement, so he passed from the mathematical pendulum to an actual case of a pendulum's movement in a resistant medium.

The seventh section of the second book is devoted to the problem of movements of liquids and the resistance of a thrown body.

In it problems of hydrodynamics are considered, among them the problem of the efflux of liquids and the flow of water through tubes. As was above shown, all these problems are of cardinal importance in the construction and equipment of canals and locks and in planning water-pumping equipment.

In the same section the laws governing the fall of bodies through a resistant medium (water and air) are studied. As we know, these problems are of considerable importance in determining the trajectory of a thrown body and the trajectory of a shot.

The third book of the 'Principia' is devoted to the 'System of the World.' It is devoted to the problems of the movements of planets, the movement of the moon and the anomalies of that movement, the acceleration of the force of gravity and its variations, in connection with the problem of the inequality of movement of chronometers in sea-voyages and the problem of tides.

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

In 1713 Parliament passed a special bill to stimulate investigations in the sphere of determining 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 movement of the pendulum, begun by Huygens, was of great importance to navigation, consequently in the third book Newton studies the problem of the second pendulum and subjects to analysis the movement of clocks during a number of ocean expeditions: that of Halley to St. Helena in 1677, Varenne's and de Hais's voyage to Martinique and Guadeloup in 1682, Couple's journey to Lisbon, etc. in 1697, and a voyage to America in 1700.

When analysing the causes of tides Newton subjects the height of flow tides in various ports and river mouths to analysis, and discusses the problem of the height of flows in dependence on the local situation of the port and the forms of the flow.

This rough outline of the contents of the 'Principia' exhibits the complete coincidence of the physical thematics of the period, which arose out of the needs of economics and technique, with the main contents of the 'Principia,' which in the full sense of the word is a survey and systematic resolution of all the main group of physical problems. And as by their character all these problems were problems of mechanics, it is clear that Newton's chief work was a survey of the mechanics of the earth and the heavenly bodies.

THE CLASS STRUGGLE OF THE ENGLISH REVOLUTIONARY EPOCH AND NEWTON'S PHILOSOPHIC OUTLOOK.

It would, however, be too greatly simplifying and even vulgarising our object if we began to quote *every problem* which has been studied by one physicist or another, and every economic and technical problem which he solved.

According to the materialistic conception of history, the final determining factor in the progress of history is the creation and recreation of actual life.

But this does not mean that the *economic factor* is the sole determining factor. Marx and Engels severely criticised Barth for narrowing down historical materialism to such a primitive conception.

The economic position is the foundation. But the development of theories and the individual work of a scientist are affected by various superstructures, such as political forms of class war and the results, the reflection of these wars on the minds of the participants—political, juridical, philosophic theories, religious beliefs and their subsequent development into dogmatic systems.

Therefore, when analysing the thematics of physics we took the main, cardinal problems on which the attention of scientists was riveted in that epoch. But, in order to understand how Newton's work proceeded and developed and in order to explain all the features of his physical and philosophic creative powers, the above general analysis of the economic problems of the epoch would not be sufficient. We must analyse more fully Newton's epoch, the class struggles during the English Revolution, and the political, philosophic and religious theories as reflected in the minds of the contemporaries of these struggles.

When Europe emerged from the Middle Ages, the rising town bourgeoisie was its revolutionary class. The position, which it occupied in the feudal society had become too restricted for it, and its further free development had become incompatible with the feudal regime.

The great struggle of the European bourgeoisie against feudalism reached its greatest intensity in three important and decisive battles: (1) the Reformation in Germany, with the political rising of Franz Zikkengen and the Great Peasant War which followed it. (2) The Revolution of 1649-1688 in England. (3) The Great French Revolution.

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

Feudalism in England had been undermined from the times of the Wars of the Roses. The English aristocracy at the beginnig of the XVII century was of very recent origin. Out of 90 peers, sitting in Parliament in 1621, 42 had received their peerages from James I, whilst the lineage of the others dated back only to the XVI century.

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

It was the urban bourgeoisie that began the English Revolution and the middle-class peasant yeomanry brought it to a. victorious end.

1689 was the compromise between the rising bourgeoisie and the former great feudal landlords. Far from opposing the development of industry, the English aristocracy of the times of the Henry VII tried, on the contrary, to extract gain from it.

The bourgeoisie was becoming the acknowledged, though a modest section of the ruling classes of England.

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

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 which actually stood at the head of the movement.

The proletariat and those strata of the urban population which did not belong to the bourgeoisie, either did not yet have any interests separate from the bourgeoisie, or did not form an independently developed class or part of a class.

Therefore, wherever they arose against the bourgeoisie, as for instance, in 1793-4 in France, they fought only for the realisation of the interests of the bourgeoisie, though not in the bourgeois fashion.

The whole of the French terror is nothing but a plebian chastisement of the enemies of the Revolution: absolutism and feudalism. The same may be said of the movement of the Levellers during the English Revolution.

The Revolutions of 1648 and 1789 were not essentially English or French Revolutions. They were, in essence, European revolutions. They not only represented the victory of a single definite class over the old political structure, but they heralded the political structure of a new European society.

"The Bourgeoisie conquered in them. But the victory of the Bourgeoisie then meant the victory of the new social regime, the victory of bourgois over feudal property rights, the victory of the nation over provincialism, of competition over trade guilds, the division of property over primogeniture, the owner's possession of the land instead of being enslaved to the land, the victory of education over superstition, of family over family name, of industry over heroic indolence, of bourgeois rights over mediæval privileges."

The English Revolution of 1649-1688 was a bourgeois revolution. It gave power to the "profiteers" who had sprung from the capitalists and landowners. The Restoration did not mean at all the re-establishment of the feudal system. On the contrary, in the Restoration the owners of land destroyed the feudal system of land ownership. In essence, Cromwell was doing the work of the rising bourgeoisie. The pauperisation of the population, as the forerunner to the creation of a free proletariat, is particularly marked after a revolution. It is in this change of the ruling class that the true meaning of a revolution is to be found. The new economic system then forming produces a new governing class. Herein lies the main difference between the interpretation of Marx and those of traditional English historians, and particularly those of Hume and Macaulay.

Like a true Tory, Hume views the importance of the Revolution of 1641 and the Restoration, and then the Revolution of 1688, only from the aspect of the destruction and re-establishment of order.

He severely condemns the upheaval caused by the first Revolution and welcomes the Restoration as a means of re-establishing order. He sympathises with the Revolution of 1688 as a constitutional act, although he does not consider that this Revolution brought about the simple restoration of the old freedom. It opens a new constitutional epoch, giving "predominance to the popular element."

To Macaulay the Revolution of 1688 is closely connected with the first Revolution. But the Revolution of 1688 is to him 'the glorious revolution' just because it is a constitutional one.

He wrote his History of 1688 immediately after 1848, and everywhere his fear of the proletariat and its possible victory is evident. He relates with proud joy 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 non-historical truth, unconnected with the dominant class, and thus the way to understanding the actual essence of the Revolution is closed.

Such was the distribution of class forces after the English Revolution. The fundamental philosophical tendencies of the epoch directly preceding the English revolution and following it were: Materialism, which originated from Bacon, and was introduced into Newton's epoch by Hobbes, Tolland, Overton and partly by Locke, Idealistic sensualism, as presented by Berkeley (H. Moore was closely associated with this). Further, a fairly strong trend of moral philosophy and Deism, represented by Shaftesbury and Bolingbroke.

All these philosophic tendencies existed and developed in the complicated conditions of class struggle, the main features of which have been outlined above.

From the time of the Reformation the Church became one of the chief bulwarks of the sovereign power. The Church organisation is a component part of the State system, and the King is the head of the State Church. James I was fond of saying—" Where there is no Bishop, there is no King."

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

The struggle against the absolute power of the King is 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 carried on under the flag of religious democracy and tolerance.

The collective name of " Puritans " applies to all partisans of the purification and democratisation of the ruling church. One must distinguish among the Puritans, however, the movement of the more radical Independents from that of the more conservative Presbyterians. These two movements formed the basis of political parties.

The partisans of the Presbyterians were mainly the representatives of well-to-do merchants and the urban bourgeoisie. The Independents drew their supporters from the ranks of the rural and urban democrats.

Thus both the class struggle of the bourgeoisie against absolutism and the struggle of the movements within the ranks of the bourgeoisie and peasantry were waged under the cloak of religion.

The religious tendency of the bourgeoisie was still further strengthened by the development of materialistic teachings in England.

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

Bacon was the originator of materialism. His materialism arose out of the struggle with the mediæval scholastics. He wanted to release humanity from the old traditional prejudices and to create a method for controlling the forces of Nature. In his teachings were hidden the seeds of the manifold development of this doctrine. " Matter smiles with its poetic, sensitive gleam at all humanity " (Marx).

In the hands of Hobbes, materialism became abstract and one-sided. Hobbes did not evolve Bacon's materialism, but only systematised it. Sensuality lost its bright colours and was transformed into the abstract sensuality of a geometrist. All the variety of motion was sacrificed to mechanical movement. Geometry was proclaimed as the dominant science (Marx). The living soul was cut out of materialism, and it became hostile to mankind. This abstract, calculating, formally mathematical materialism could not stimulate to revolutionary action.

That is why the materialistic theory of Hobbes did not interfere with his monarchical views and defence of absolutism. After the victory of the Revolution of 1649 Hobbes went into exile.

But contemporaneously with the materialism of Hobbes there existed another materialistic movement, indissolubly bound up with the true revolutionary movement of the Levellers. At the head of this movement was Richard Overton.

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

The fate of this fighter and philosopher is curious. Whilst the name of Hobbes is widely known and to be found in all text-books on philosophy, one cannot find a single word about Overton not only in the most detailed bourgeois primer of philosophy, but even in the most complete biographical encyclopædias.

Richard Overton did not write much. He changed the pen too often for the sword and philosophy for politics. His treatise " Man is mortal in all respects " was published in the first edition in 1643, and the second edition in 1655. It is a strikingly materialistic and atheistic composition. Immediately after its appearance it was condemned and prohibited by the Presbyterian Church.

The manifesto of the Presbyterian Assembly directed against unbelief and false religions calls down all the curses on Richard Overton's head. " The chief representative of the terrible doctrine of materialism," declares the manifesto—" rejecting 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 Overtpn's doctrine, and his fate—a most interesting page in the history of English materialism, but will only mention one point from the publication mentioned, in which Overtpn formulated very clearly the basic principles of his materialistic doctrine.

In criticising the contrast of the body as inert matter to the soul as the active, creative principle, Overton writes:

" Form is always the form of matter, and matter is the material for form. Each of them cannot exist by itself alone but only in unity with the other, and only in unity do they form a thing.

" Everything created is created from natural elements (Overton uses the term ' elements ' in the sense of the ancient Greeks: water, air, earth). But everything created is material, because that which is not material does not exist."

As distinct from England, materialism on French soil was the theoretical standard 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, and the main struggle went on under the cloak of religion.

English materialism as preached by Hobbes proclaimed itself a philosophy most suited for scientists and educated people, as against religion, which was good enough for the uneducated masses, including the bourgeoisie.

Together with Hobbes, cut off from his active revolutionism, materialism went to the defence of the royal authority and absolutism, and encouraged the repression of the people.

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

Therefore the " misanthropic " materialism of Hobbes was hateful to the bourgeoisie, not only because of its religious heresy but because of its aristocratic connections.

Because of this and in opposition to the materialism and deism of the aristocracy, it was the Protestant sects, who produced the cause and the fighters against the Stuarts, who also provided the chief fighting forces of the progressive middle class (Engels).

But still more hateful to the bourgeoisie than the esoteric materialism of Hobbes was the materialism of Overton, a materialism which was the banner of the political struggle against the bourgeoisie, a materialism which approached a militant atheism and which fearlessly opposed the very bases of religion.

Newton was the typical representative of the rising bourgeoisie, and in his philosophy he embodies the characteristic features of his class. We may, with every right, apply to him that characterisation which Engels applied to Locke. He also was a typical son of the class compromise of 1688.

Newton was the son of a small farmer. His position in the University and in society until his appointment as a Warden of the Mint (1699) was a very modest one. By his connections also he belonged to the middle classes. His philosophic relations were nearest to Locke, Samuel, Clarke and Bentley.

In his religious beliefs Newton was a Protestant. He was an ardent supporter of religious democracy and tolerance. We shall see later that the religious beliefs of Newton were a component part of his, world-outlook.

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 over the question of the possibility of taking the oath to " the illegal Ruler "—William of Orange—arose, and matters even developed to the point of disorders in Cambridge, Newton, who as Member of Parliament for the Cambridge University had to take the oath from the University, was in favour of the oath of allegiance and the recognition of William of Orange as King.

In his letter to Doctor Cowell Newton adduced three arguments in favour of taking the oath to William of Orange, which were to remove any doubts as to the possibility of taking the oath by those members of the University who had previously sworn fidelity to the deposed King.

The reasoning and arguments of Newton remind one strongly of the opinions of Macaulay and Hume, which were mentioned above.

This ideological characteristic of Newton, who was the child of his class, explains why those materialistic germs which were hidden in the " Principia " did not grow in Newton into a fully formed structure of mechanical materialism, similar to the Physics of Descartes, but intermingled with his idealistic and theological beliefs, which, in philosophical questions, even subordinated the material elements of Newton's Physics.

The importance of the " Principia " is not confined only to technical matters. Its very name indicates that it forms a system, a conception of the universe. Therefore it would be incorrect to limit the analysis of the contents of the " Principia " to determining its intrinsic connection with the economics and technology of the epoch which served the needs of the rising bourgeoisie.

Modern natural science is indebted for its independence to its freedom from teleology. It recognises only the causative study of Nature.

One of the fighting slogans of the Renaissance was; " True knowledge only through knowledge of Causes " (*vere scire per causas scire*).

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

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

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

The universal acceptance of the principle of mechanical causation as the sole and basic principle of the scientific investigation of Nature is due to 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," but so far only in the realm of inorganic nature and in the field of terrestrial and celestial mechanics.

The basic idea of the " Principia " consists of the conception of the movement 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.

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

The acceptance of the modality of movement, and the rejection of moving matter as *causa sui* was bound inevitably to bring Newton to the conception of the original impulse. From this aspect, the conception of divinity in Newton's system is not a casual one, but is organically connected with his views on matter and motion, as well as with his views on space, in the development of which Henry Moore had a great influence on Newton.

It is at this point that the entire weakness of Newton's general philosophic conception of the universe becomes apparent. The principle of pure mechanical causation leads to the understanding of the divine element. " The absurd

infinity " of the universal chain of mechanical determinism is closed by the original impulse, and thus the door of teleology is opened.

Thus, the importance of the " Principia " is not confined to purely physical problems, for it is of great methodological interest.

In the third book of the " Principia " Newton expounds a " conception of the universe." In the general scholium, to the third book (third edition) the indispensability of a divine power is proved as creating, moving and directing elements 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." A great deal of literature exists on this question, but the letters from Newton quoted below undeniably prove that Newton's theological views were not tacked on 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, for eight lectures to be read annually in one of the Churches in England, in which proofs of the irrefutability of Christianity were to be given and unbelief repudiated.

Bentley, Chaplain of the Bishop of Worcester, had to read the first series of these lectures. He decided to devote the seventh and eighth to the necessity of the existence of divine providence. He decided to take the proofs for this from consideration of the physical principles of the creation of the world as they are given in Newton's " Principia."

When preparing these lectures he met with a series of physical and philosophic difficulties, for the explanation of which he approached the author of the " Principia."

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

The chief difficulty on which Bentley approached Newton was how to repudiate the materialistic argument brought forward even by Lucretius, that the creation of the world could be explained by purely mechanical principles, if it be assumed that matter possesses its immanently inherent property of gravity and is equally 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 here it is the question of the theory of the evolution of the universe that is referred to, and on this question Newton is the resolute opponent of a materialistic conception of evolution.

"When I wrote the third book of the 'Principia'" writes Newton to Bentley, "I paid special attention to those principles which could prove to intellectual people the existence of Divine power."

If matter were equally distributed in finite space, then, owing to its power of gravity, it would collect into one large spheric mass. But if matter were distributed in infinite space, then it could, in obedience to the force of gravity, form masses of various magnitudes.

However, in no case is it possible to explain by natural causes how the luminous mass—the sun—is in the centre of the system and actually in the position in which it is situated.

Therefore the only possible explanation is 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, as a consequence of natural causes, can move, Newton pointed out to Bentley that as a consequence of the force of gravity, which is a natural cause, planets can move, but can never achieve periodical rotation on closed orbits, as for this a tangential component is required. Therefore, concludes Newton, in no case is it possible to explain the actual paths of the planets or creation by natural causes, and therefore, on enquiring into the structure of the universe the presence of an all-wise divine element is apparent.

Further, discussing the question of the stability of the solar system, Newton pointed out that such a wonderfully arranged system, in which velocity and masses of bodies are so selected that it retains stable equilibrium, could only be created by a divine mind.

This conception and Newton's appeal to a divine mind as the highest element, creator and prime motive power of the universe, is not in the least accidental, but is the essential consequence of his conception of the principles of mechanics.

Newton's first law of motion attributed to matter the faculty of retaining 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 inertia or mechanical transference.

Matter, on which outside forces have no influence, can exist either in a state of inertia or in a state of rectilinear, proportional movement. If a material body is inert, then only an outside force can bring it out of that state.

If, however, a body is in motion, then onlv an extrinsic force can change that motion.

Thus, movement is not an immanently inherent attribute of a body, but is a modus which matter possibly does not possess.

In this sense Newton's matter is inert in the full meaning of the word. An outside impulse is always necessary to bring it into movement or to alter or end this movement.

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

It is clear that such a conception of the modality of movement must inevitably lead to the introduction of an extrinsic motive force, and with Newton this role is filled by God.

It is very important to note that in principle Newton is not only not opposed to the idea of determining matter by definite attributes, but, contrary to Descartes, declares density and weight to be "immanent qualities of matter."

Thus, denying to movement the character of being an attribute of matter, and accepting it only as a modus, Newton consciously deprives matter of that inalienable property without which the structure, and creation 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 say quite openly"—the latter declares—"that in the nature of bodily things I do not recognise anv other than that which can be separated in the most distinct manner, can take on form and move, which mathematicians call quantity and make the subject of their demonstrations; that in this matter I consider only its separation, forms and movement and do not accept anything as the truth which does not ensue from these principles as clearly as with the authenticity of mathematical statements. By this means all the phenomena of Nature can be explained. Therefore I hold the view that in Physics other principles from those laid down here are neither necessary nor permissible."

In his physics, Descartes does not admit 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 the limits of his Physics matter represents a single substance, the only basis of existence and knowledge (Marx).

In the third part of his "Principia" Descartes also gives a picture of the development of the universe. The difference in position taken up by Descartes consists in his considering in detail the historical genesis of the universal and solar systems in accordance with the principles mentioned above.

It is true that Descartes, also, considers movement only as the modus of matter, but, in contrast to Newton, with him the supreme law is the law of conservation of the quantity of motion. Separate material bodies can acquire and lose movement, but the general quantity of movement in the universe is constant.

In Descartes law of the conservation of the quantity of movement is included the assumption of the indestructibility of movement.

It is true, Descartes understood indestructibility in the purely quantitative sense, and such a mechanical formulation of the law of conservation of movement is not accidental, but arises from the fact that Descartes, like Newton, takes the view that all varieties of movement consist of mechanical transposition. They do not consider the problem of transition from one form of movement to another, and this, as we shall see in the second part of this paper, is for profound reasons.

Engel's great merit is the fact that he considered the process of the movement of matter as eternal transition from one form of material movement to another. This enables him not only to establish one of the basic theses of dialectic materialism, i.e., the inseparability of movement from matter, but also to carry the conception of the law of conservation of energy and quantity of movement to a higher level.

Descartes also introduced God, but his god is necessary to him only to prove that the quantity of movement in the universe remains constant.

He not only does not accept the conception of an outside impulse from God in regard to matter, but, on the contrary, considers that constancy is one of the basic attributes of divinity and therefore in his creations we cannot assume any inconstancy, as by expecting inconstancy in his creations we assume inconstancy in him.

Thus Descartes' reason for introducing a divinity is different from Newton's, but a divinity is also necessary in his conception, as Descartes also does not pursue the view of the self-movement of matter to its logical conclusion.

During the period when Descartes and Newton were working out their conceptions of matter and movement, although somewhat later (the nineties of the XVII century), we find in John Tolland also a consequential materialistic conception of the correlation of matter and movement.

Criticising the beliefs of Spinosa, Descartes and Newton, Tolland directed his chief attack against the conception of the modality of movement.

" Movement," contended Tolland in his fourth letter to Sirene, " is a most essential attribute of matter, just as inseparable from it as gravity, impenetrability and dimension. It must enter as a component part into its determination."

" This is the only conception"—Tolland quite justly avers, " that provides a rational explanation of the law of the quantitative constancy of movement. It solves all the difficulties regarding motive forces."

The teaching of the self-movement of matter received its full development in the dialetical materialism of Marx, Engels and Lenin.

The entire progress of modern Physics demonstrates the truth of this teaching. In modern Physics, the view of the inseparability of movement from matter is being more and more accepted.

Modern Physics rejects absolute inertia.

As a result of the universally accepted importance of the law of the conservation and transmutation of energy, the conception of the correlation of the forms of movement of matter which was developed by Engels is being more and more confirmed. It is the only conception giving a true understanding of the law of transmutation of energy, as it synthesises the quantitative side of this law with its qualitative side, uniting it organically with the self-movement of matter.

The connection of the law of inertia and the conception of inert matter with Newton's absolute space has been indicated above.

But Newton did not confine himself only to the physical conception of space, but gave also a philosophic-theological conception.

Dialetical materialism considers space as a form of existence of matter. Space and time are the root conditions of the existence of all beings, and therefore space is inseparable from matter. All matter exists in space, but space exists only in matter. Empty space divorced from matter is only a logical or mathematical abstraction, the fruit of the activities of our minds, to which no real thing corresponds.

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

Material bodies are found in space, as in a kind of receptacle. Newton's space is not a form of the existence of matter, but only a receptacle independent of these bodies and existing 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 determined space as a receptacle, separated from matter, Newton, naturally, asks himself the question what is the essence of this receptacle.

In solving this question Newton concurs with H. Moore, who held the view that space is " the sensorium of God."

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

The unsatisfactory nature of the conception of Descartes 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 found in space devoid of matter, asks Newton in question 28 in " 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 immaterial, intellectually gifted, omnipresent being for whom space is the sensorium, through which it perceives things and conceives them in their essence?

Thus we see that in this question also Newton decidedly accepts the viewpoint of theological idealism.

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

Whilst in Descartes we find a sharply defined dualism in his physics and metaphysics, in Newton, particularly in his later period, we not only do not find any desire to separate his physical conception from the philosophical, but he even, on the contrary, attempts in his " Principia " to justify his religio-theological views.

In so far as the " Principia " arises in the main from the requirements of the economy and technology of the epoch and studies the laws of the movement of material bodies, the book undoubtedly has elements of healthy materialism.

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

So that in his philosophic as well as in his religious and political views Newton was a child of his class. He ardently opposed materialism and unbelief.

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

In his letter of the 16th September 1693 he asked Locke to forgive him for this letter and for having thought that Locke's system affects moral principles. Newton particularly asked forgiveness for having considered Locke as a follower of Hobbes.

Here is found the confirmation of Engels' statement that Hobbes' materialism was hateful to the bourgeoisie.

There is no need even to speak of Overton's materialism —he was, after all, almost a Bolshevik.

When Leibnitz, in his letters to the Princess of Wales, accused Newton of materialism because he considered space as the sensorium of divinity, by which he conceives things, which, consequently do not wholly depend on him and are not created by him, Newton fiercely protested against such accusations. Clarke's polemics with Leibnitz had as their object the rehabilitation of Newton from this accusation.

In the realm of physics Newton's researches remain in the main within the bounds of one form of movement—that is, mechanical transposition, and therefore contain no conception of development and transition from one form of movement to another, and in the realm of his views on Nature as a whole the conception of development is entirely absent in Newton.

Newton closes the first period of the new natural science in the field of the inorganic world. It is a period of mastery of the material available. In the realm of mathematics, astronomy and mechanics he achieved great results, particularly as regards the work of Kepler and Galileo, which Newton completed.

But all historical outlook on nature is lacking. As a system it is absent in Newton. Natural science, revolutionary in its origin, comes to a halt in face of conservative nature, which from century to century remains the same as it was created.

Not only is the historical view of nature lacking in Newton, but in his system of mechanics the law of the conservation of energy does not exist. This is all the more incomprehensible, at first sight, in view of the fact that the law of conservation of energy is a simple mathematical consequence of the central forces with which Newton deals.

Further, Newton considers, for instance, cases of oscillation, in explanation of which Huygens, studying the question of the centre of oscillations, gave vague enunciation to 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 which prevented Newton from enunciating this law, even in the form of an integral of vital forces.

In order to explain this we must consider the question from the viewpoint of our Marxian conception of the historical process. Such an analysis will enable us to discuss this question in connection with the problem of transition from one form of motion to another, to which the solution was provided by Engels.

ENGELS' CONCEPTION OF ENERGY AND NEWTON'S LACK OF THE LAW OF CONSERVATION OF ENERGY.

In analysing the problems of the inter-relationships of matter and motion in Newton we saw that Tolland took the view that motion was inseparable from matter. Nevertheless, the simple recognition of the inseparability of matter from motion far from resolves the problem of studying the forms of matter's movement.

In nature we observe an endless variety of forms of the movement of matter. If we stop to consider the forms of the movement of matter studied by physics we see that here also are a number of different forms of movement (mechanical, thermal, electro-magnetical).

Mechanics studies that form of motion which consists in the simple passage of bodies through space.

Nevertheless, in addition to this form of motion we have a number of other forms of the movement of matter, in which the mechanical transposition drops to second place by comparison with the new specific forms of motion.

The laws of the movement of electrons, although they are connected with their mechanical transposition, do not amount to their simple transposition in space.

Consequently, in distinction from the mechanical viewpoint, which regards the main task of natural science as the reduction of all the complex aggregation of the movements of matter to one form of mechanical transposition, dialectical materialism regards the main task of natural science as the study of the forms of movement of matter in their inter-connections, inter-relationships and development.

Dialectical materialism understands movement to be change in general. Mechanical transposition is only one, partial form of movement.

In real matter, in nature we never meet with absolutely isolated pure forms of movement. Every real form of movement, including, of course, mechanical transposition, is always bound up with the transition of one form of movement into another.

Hitherto physics has remained within the bounds of studying one form of movement, the mechanical form, and as we have seen this constitutes the peculiarity of Newton's physics; the problem of inter-relationships between this form and other forms of movement could not truly be set. And when such a problem was set there was always a tendency to hypostasise just this most simple and most fully studied form of movement and to put it forth as the sole and universal aspect of motion.

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

In the introduction to the " Principia " Newton directs attention to the circumstance that " it would be desirable to deduce from the elements of mechanics the remaining phenomena of nature." (Newton deduced the motion of the planets from these laws in the third book.) " A great deal forces me to assume," he continues, " that all these phenomena (of nature) are conditioned by forces, by which the particles of bodies, in consequence of causes so far unknown, are either attracted one towards another and accumulate in a true figure, or else are mutually repelled and separate one from another."

With the development of large-scale industry the study of the new forms of movement of matter and their exploitation for the needs of production come to the forefront.

The steam engine gave a mighty impulse to the development of the study of the new, thermal form of movement. The study of the history of the development of the steam engine is of importance to us in two regards.

First and foremost we study the problem why it was that the development of industrial capitalism and not that of merchant capital raised the problem of the steam engine. This will explain why the steam engine became the central object of investigation not in Newton's time but in the period immediately following, although 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 thermo-dynamics 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 of interest to us in another direction. In distinction from mechanical machines (the block, the windlass, the lever) in which one aspect of mechanical movement is transformed into another aspect of the same mechanical transposition, by its very essence the steam engine is based on the transformation of one form of movement (thermal) into another form (mechanical).

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

We first turn to a study of the chief stages of development of the steam engine in connection with the development of productive forces.

Marx noted that the mediæval commerce of the first trading cities was of an intermediary character. It was founded on the barbarism of the producing peoples, for whom the trading cities and merchants played the rôle of middle-men.

So long as merchant capital played the role of middle-man in the exchange of produce of undeveloped countries merchant profit was not merely the result of cheating and trickery, but directly originated from them. Later merchant capital utilised the difference in price 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 landowner or the eastern despot, concentrating the main mass of surplus product in its oWn hands and being comparatively little interested in the prices of commodities.

This explains the enormous profits of the 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.

In 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 which 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 the overwhelming hegemony belongs everywhere to merchant capital it constitutes a system of despoliation.

The high rates of profit were maintained in the 17th and the beginning of the 18th centuries. This is to be explained by the circumstance that the extensive trade of the late middle ages and the beginning of the new times was mainly monopolistic commerce. The British East Indian Company was closely connected with the State government. Cromwell's navigation act strengthened the monopoly of British trade. The gradual decline of Holland as a naval power dates from that time and *a* sound basis is laid to England's maritime hegemony.

Thus, so long as the dominant form of capital was merchant capital, chief attention was directed not so much to the improvement of the actual process of exchange, but to the consolidation of the monopolistic position and to domination in the colonies.

Developing industrial capitalism at once turned its attention to the process of production. The free competition within the country which the British bourgeoisie achieved in 1688 forced an immediate consideration of the problem of costs of production.

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

It is necessary not only to produce commodities of good quality and in sufficient quantities, but to produce them as cheaply as possible.

The process of cheapening production of commodities was directed along two lines: the continually 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 did not reduce the labour day but on the contrary, being a mighty weapon for the increase of the productivity of labour, as an instrument of capital, it simultaneously became the means of an immeasurable extension of 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 machine, since on this question there exists a radical difference between the point of view of Marxism and that of other investigators.

Meantime, in order to elucidate the essence of the industrial revolution which raised the steam engine to one of the foremost places, it is necessary to have a clear understanding of the rôle played by the steam engine in the industrial revolution.

There is a very widely held view that the steam engine created the industrial revolution. Such an opinion is erroneous. Manufacture develops out of handicrafts by two roads. 'On the one hand it arises from a combination of heterogeneous independent handicrafts, which lose their independence, on the other hand it arises from the co-operation of craftsmen in the same craft, disintegrating the particular process into its component parts and passing 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 in manufacture also the problem of the motive power is an important one, but the revolutionisation of all processes of production which was prepared by a detailed division of labour within the bounds of manufacture came not from the motive power but from the executive mechanism.

Every machine consists of three basic parts: the motive power, the transmission mechanism and the executing instrument. The essence of an historical view of the definition of a machine consists in the fact that in various periods a machine has various purposes.

The definition of a machine given by Vitruvius was preserved down to the industrial revolution. For him a machine was a wooden instrument of the greatest service in the lifting and transport of weights.

Consequently the basic contrivances serving these ends: a sloping plane, the windlass, the block, the lever, received the name of simple machines.

When analysing in the " Principia " the nature of the applied mechanics worked out by the ancients Newton attributes to them the teachings of five simple machines: the lever, the wheel, the block, the windlass, the wedge.

Hence arises the opinion found in English literature that an instrument is a simple machine and a machine a complex instrument.

But it is not entirely a question of simplicity and complexity. The essence of the matter consists in the fact that the introduction of executing mechanism, the function of which consists in seizing and expediently changing the object to be subjected to labour, brings about a revolution in the very process of production.

The two other parts of the machine exist in order to bring the executing mechanism into motion.

Thus it is clear what a gulf divides the machines known to Vitruvius and which accomplish only the mechanical transposition of the finished products, and the machine of large-scale industry, the function of which consists in the complete transformation of 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 literature.

In his " Theoretical Kinematics " Releau defines a machine as the combination of bodies capable of resisting opposition, and which are built so that by means of their mechanical power the powers of nature are compelled, given certain movements, to bring about an activity.

This definition is equally applicable to Vitruvius' machine and to the steam engine. Although when applying it to the steam engine we meet with difficulties.

The same defect distinguishes the definition of a machine given by Sombart. Sombart calls the machine a means or a complex of means of labour, tended by a man, the purpose of which is the mechanical rationalisation of labour. The machine as a means of labour is distinguished from the instrument of labour by the circumstance that it is tended by a man, whereas the machine as an instrument attends a man.

The unsatisfactory nature of this definition consists in its making the basis of the difference between an instrument and a machine the circumstance that the one serves a man and the other is served by man. This definition, based at first sight on a social economic symptom, not only gives no idea of the difference between the period in which the simple instrument predominates and the period in which the machine method of production predominates, but creates quite an absurd idea that the essence of the machine consists in its being served by man.

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

Marx's definition of a machine directs attention to the circumstance that it causes a revolution in the very process of production.

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 Wyate invented his first spinning machine he did not even mention how it was set in motion. "A machine in order to spin without the aid of fing-ers '' was his programme.

Not the development of the motor and the invention of the steam engine created the industrial revolution of the 18th century, but on the contrary the steam engine gained such enormous importance just because the division of labour developing in manufacture and the increasing productivity made it possible and necessary to invent an accomplishing instrument, and the steam engine, which had been born in the mining industry, found a field awaiting its application as a motor.

Arkwright's spinning jenny was at first set in motion by means of water. Meantime the employment of water power as the predominant form of motive power was accompanied with great difficulties.

It was impossible to raise it to a productive level, it was impossible to overcome its defects, sometimes it was exhausted, and it always retained a purely local significance.

Only with the invention of Watt's machine did the machine textile industry, already developed sufficiently, receive the motor without which it could not manage at the stage of development it had reached.

Thus the machine textile industry is not in the least a consequence of the invention of the steam engine.

The steam engine was brought to light in connection with raining. As early as 1630 a patent was granted in England to Ramsay for '' raising water with the aid of fire during deep mining works.''

In 1711 a '' Society for raising water with the aid of fire '' was formed for exploiting Newcomen's machine in England.

The greatest service, writes Carnot, in his work '' On the moving power of fire," rendered by England's thermal (steam) engine is undoubtedly the revival of the activities of coal mines, which threaten to choke owing to the continually growing difficulties of pumping the water and raising the coal.

The steam engine gradually becomes an important factor in production. Then attention is at once directed to what can be done to make the machine more economical by reducing the expenditure of steam, and consequently the expenditure of water and fuel.

Even before Watt's work Smeaton was occupied with investigating the expenditure of steam in various steam engines, founding a special laboratory in order to do so in 1769. He found that the expenditure of steam varies according to the machine from 176 to 76 kg. per horse-pow'er hour. Savory succeeded in building a machine of the Newcomen, type with an expenditure of steam of 60 kg. per horse-power hour.

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

It is obvious that the problem of economy was one of the most fundamental problems confronting Watt.

Watt's patent, taken out in 1769, begins thus : '' My method of diminishing the consumption of steam in fire machines, and thus the expenditure of burning material, consists in the following basic propositions.''

The agreement which Watt and Bolton concluded with the owner of coal-mines consisted in their receiving in monetary form one-third of the sum received by the saving of expenditure on fuel.

Under this condition from one mine alone they received over two thousand pounds in one year.

The chief inventions of the textile industry were made during the period 1735 to 1780, and thus a potential demand for motors already existed.

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

The problem of technical rationalization of the steam engine became a central one. The realization of this task in practice made necessary a detailed study of the physical processes carried out in the machine.

In distinction from Newcomen, in the laboratory of Glasgow University Watt studied the thermo-dynamic qualities of steam in detail, and thus laid 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 connection with the changes in elasticity of steam. Then he investigated the latent temperature of steam formation and developed and checked Black's theory.

Thus the chief problems of thermodynamics, the teaching on the latent temperature of steam formation, the dependence of the boiling point on pressure and the height of the latent temperature of steam formation began to be scientifically worked out by Watt.

It was this detailed study of the physical processes in the steam machine that enabled Watt to go further than Smeaton, who, although he set himself the task of the laboratory investigation of the steam machine, could not go beyond the purely empirical, superficial improvement of Newcomen's machine, as he was not acquainted with the physical qualities of water vapours.

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

The necessity arose not only of studying the separate physical processes in the steam machine, but the general theory of steam machines, the general theory of the coefficient of profitable activity of the steam machines. This work was carried out by Carnot.

The general theory of the steam machine and the theory of the coefficient of profitable activity led Carnot to the necessity of investigating the general thermic processes, to the discovery of the second element of thermodynamics.

The study of steam machines, said Carnot in his work "On the Motive Power of Fire" (1824) is extraordinarily interesting, as their importance is very considerable and their employment increases with every day. Clearly they will cause a great revolution in the civilized world.

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

Carnot formulated his task of discovering the theory of the steam machine in such a way that the practical tasks set by him in order to discover the general theory of the coefficient of useful service were quite clear.

The question is frequently asked, he says, whether the motive power of heat is limited or unlimited; by motive power we mean the useful service which a motor can provide.

Is there any limit to the possible improvements, a limit which the nature of things renders insurpassable by any means whatever? or, on the contrary, are unlimited improvements possible?

Machines that do not derive their motion from heat, but have the motive power of man, animals, the fall of water, the current of air, can be studied, Carnot observes, by means of theoretical mechanics.

Here, all possibilities are foreseen, all possible movements are reduced to general principles (this was made possible owing to Newton's work on mechanics), are firmly established and applicable in all circumstances.

No such theories exist in the case of thermal machines. It will be impossible to establish them, Carnot declared, until the laws of physics are sufficiently extended and sufficiently generalized to make it possible to see in advance the results of a definite reaction of heat on any particular body.

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 machine is important to us in another connection also.

The historical succession in the study of various forms of physical motion of matter is : mechanics, heat, electricity.

We have seen that the development of industrial capitalism faced technology with the demand for the creation of a universal motor.

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

The problem of the theory of the coefficient of useful service of steam machines led to the development of thermodynamics, i.e., to the study of the thermal form of movement.

This consequently explains the historical succession in the study of forms of movement; following on mechanics we get the development of the study of thermal forms of motion: thermodynamics.

We now pass to a consideration of the importance of the steam engine from the aspect of the transformation of one form of motion into another.

Whilst Newton never considered even the problem of the law of the conservation and transformation of energy, Carnot was compelled, although truly in an indirect form, to consider it.

This was just because Carnot engaged in the study of the steam engine from the aspect of the transformation of thermal into mechanical energy.

The category of energy as one of the basic categories of physics appears when the problem of the inter-relationships between various forms of motion comes to the forefront. And the more the richness of the forms of motion becomes the subject of study in physics, the greater the importance acquired by the energy category.

Thus the study of physical forms of motion of matter and their historical development must provide the key to an understanding of the origin, importance, and mutual connections of the categories of physics.

The historical study of the forms of motion must be carried on from two aspects. We must study the historical succession of the forms of motion as they appear in the development of physical science in human society. We have already shown the connection between the mechanical and the thermal form of motion from the aspect of their historical genesis in human society. The study of these forms proceeds in the succession that they are raised by human practice.

The second aspect is the study of the "natural science of the development of matter." The process of studying the development of inorganic matter in the microcosmos and the macrocosmos must provide the key to the understanding of the connection and mutual transitions of one form of motion of inorganic matter into another, and must lay a sound basis for the natural classification of the forms of motion of matter. This principle must lie at the basis of Marxist classification.

Every science analyses a separate form of motion or a number of forms of motion connected with one another and passing into one another.

The classification of sciences is nothing more 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 transition of one form of motion into another, as accomplished in nature.

Thus this principle of Marxist classification of science sets at the basis of classification the great idea of development and the transition of one form of matter in motion into another form. (Engels.)

Herein consists Engel's notable conception of the interconnection and the hierarchy of the forms of movements of matter.

The conception of energy is indissolubly bound up with the transformation of one form into another form of motion, with the problem of the measurement of this transformation. Modern physics emphasises the quantitative aspect of this transformation and postulates the constancy of energy through all its transformations.

We recall, as was shown in the previous chapter, that the quantitative constancy and the quantities of motion were announced by Descartes. The new element that was introduced into physics by the work of Mayer and Helmholtz consisted in the discovery of the transformation of the forms of motion and also with the constancy of energy during these transformations.

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

Owing to this discovery the various isolated forces of physics (heat, electricity, mechanical energy) which hitherto could be compared with the invariable forms of biology, were transformed into forms of motion inter-connected and passing into one another according to definite laws.

Like astronomy, physics came to the inevitable conclusion that the last result was the eternal circle of moving matter. That is why Newton's period, which worked only with one form of movement—the mechanical—and put in the forefront not the conversion of one form into another, but only the transformation and modification of one and the same form of motion—mechanical transposition—(we recall the definition of a machine given by Vitruvius and Carnot's observations) did not consider and could not consider the problems of energy.

As soon as the thermal form of motion appeared on the scene (and it appeared on the scene as indissolubly bound up with the problem of its conversion into mechanical motion) the problem of energy came to the forefront. The very setting of the problem of the steam machine (to raise water by means of fire) clearly point to its connection with the problem of the conversion of one form of motion into another. It is significant that Carnot's classic work has the title: "On the Motive Force of Fire."

This treatment of the law of the conservation and conversion of energy given by Engels, raises to the forefront the qualitative aspect of the law of conservation of energy, in contradistinction to the treatment which predominates in modern physics and which reduces this law to a purely quantitative law—the quantity of energy during its transformations. The law of the conservation of energy, the teaching of the indestructibility of motion has to be understood not only in a quantitative but also in a qualitative sense. It contains not only a postulation of the indestructibility and the increatability of energy, which is one of the basic prerequisites of the materialistic conception of nature, but a dialectical treatment of the problem of the movement of matter. From the aspect of dialectical materialism the indestructibility of motion consists not only in the circumstances that matter moves within the limits of one form of motion, but also in the circumstance that matter itself is capable of all the endless variety of forms of motion in their spontaneous transitions one into another, in their self-movement and development.

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

Newton did not see and did not solve the problem of the conservation of energy, but not because his genius was insufficiently great. Great men, no matter how notable their genius, in all spheres formulate and resolve those tasks which have been raised for accomplishment by the historical development of productive forces and production relationships.

THE MACHINE-WRECKERS OF NEWTON'S EPOCH AND THE PRESENT-DAY WRECKERS OF 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 the epoch, which were raised for accomplishment by the class entering into power.

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

Newton happened to live in this very epoch, when new forms of social relations, like new forms of production, were being created.

In his mechanics he was able to solve that complex of physico-technical problems which the rising bourgeoisie had set for decision. But he remained impotent before nature as a whole. Newton knew the mechanical transposition of bodies, but he even rejected the conception that nature finds itself in process of unceasing development. Still less can we hope to find in him any view of society as a developing entity, although it was specifically the transitional character of the epoch which gave rise to his basic 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 conception of nature as eternal and unchanging from century to century.

They were to show, albeit in a far from complete form, that the solar system is the product of historic development.

In their works the conception 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 condition solely as a consequence of natural causes, but only came into existence through their influence. God is not only unnecessary in a system existing on the basis of the laws of mechanics, but he is unnecessary even as an explanation of its origin.

" I have not found it necessary to include any hypothesis of deity in my system," so Laplace is said to have answered Napoleon's questions as to the reason for the omission of all reference to the rôle of God in his " System of the World."

The progressive development of productive forces gave rise to progressive science. That change from home handicraft industry to manufacture and from manufacture to large-scale machine industry which had only begun during Newton's period, was greatly accelerated during the following century. It was completed during the monopolistic imperialist phase of capitalism, which in turn is introductory to new, socialist forms of development.

As one phase of the capitalist method of production is replaced by another, so the very views of the governing class in capitalist society on technology and science change. Accordingly, on coming to power the bourgeoisie struggles mercilessly against the old guild and handicraft form of production. With an iron hand it introduces large-scale machine industry, shattering in its course the resistance of the worn-out feudal class and the still elemental protest of the new-born proletariat.

For the bourgeoisie science and technology are powerful weapons of struggle, and it is interested in the development and perfection of these weapons.

The glorifier of industrial capitalism (Ure) describes the struggle of the bourgeoisie for new methods of production in the following terms :—

" The horde of discontented, who considered themselves invincible behind the old methods of division of labour, saw that they were out-manoeuvred by a flank-attack, and their defensive means were destroyed by modern mechanical technique. They were forced to surrender to the mercy and wrath of the victor."

Examining further the significance of the invention of the spinning machine, he said: " This machine was destined to restore order between the industrial classes. This invention confirms the doctrine which we have already developed, that capital is continually forcing science to serve it and is forcing the rebellious hands oft labour into submission."

The bourgeoisie in power talked with the lips of Ure, as it built new methods of production with the flesh and blood of the " rebellious hands of labour."

On coming to power the bourgeoisie revolutionised the whole method of production. It rent the old feudal bonds to shreds, and shattered the archaic forms of social relations which fettered the further development of productive forces. During that period it was revolutionary, because it brought with it new and improved 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 movement of matter were discovered.

The gigantic development of technique tremendously stimulated the development of science, and the turbulently developing science in turn permeated the new technique.

And on the basis of this unprecedented flourishing of productive forces, on the basis of the tremendous growth of material culture, occurred an unprecedented impoverishment of the mass of the people, and a terrible growth of unemployment.

It is not strange that these contradictions in the predominant capitalist methods of production should have attracted the attention, not only of State officials and of capitalists, but also of the scientists.

In Newton's epoch the bourgeoisie called for new methods of production. In his memorandum on the reform of the Royal Society, Newton called on the State authorities to support science, which did so much in the study of nature and the creation of new productive forces.

To-day a very different situation obtains.

During the past year " Nature" has published a number of leading articles dealing with the questions we are considering. In these articles problems which are now agitating the whole world receive consideration. Of these articles, we will refer to two which more clearly express the point of view of English natural scientists. One is entitled " Unemployment and Hope," the other " Science and Society."

This is how these articles describe the tasks of industry, its aims and lines of development. Discussing the question of unemployment, in an analysis of capitalist society " Nature " thus defines the rôle of machines.

"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."

Modern science and technique creates machines remarkable for their accuracy and productivity, of extraordinarily complicated and delicate organisation. And, it appears that the machine-wreckers of Newton's period were wiser than we, who create machines of unprecedented complexity and power.

In the statement referred to not only is there a distortion of the ideas of Marx, but also incorrect light is thrown on the movement of the machine-wreckers.

Let us first re-establish the true historic circumstances and actual causes which provoked the workers into wrecking the machines.

The struggle of the workers against the machine is only the reflection of the struggle between wage labourers and the capitalists. Not against the machines as such did the working class of that period struggle, but against the position to which the developing capitalist order was relegating them in the new society.

During the 17th century almost all Europe seethed with the indignation of the workers against the carding machines. The first wind-power saw-mill was destroyed in London at the end of the " 70's " of the 17th century.

The first decade of the 19th century was notable for 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 which has gone out of currency. The growing working-class, still without class consciousness, directed its hatred towards the superficial forms of expression of capitalist relationships—the machines.

But this protest, reactionary in its form, was the expression of a revolutionary protest against the system of wage labour and private ownership of the means of production.

The worker actually became an accessory to the machine not because machines had been invented, but because these machines served the interest of the class owning 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 destruction of the machines, but in their protest against the slavery of wage labour.

" The comfort and 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 crushing of individuality and the suffering of the masses of the people.

Here it is permissible to ask : Why was it that during Newton's time, when there was a great development in the means of production, scientific circles not only did not call for a retardation of this development, but, on the contrary, in every way encouraged every new discovery and invention ; and the organ of the foremost natural scientists of Newton's epoch, " 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, according to its views are the results of too great a development of productive forces.

These methods are outlined in the leading article, " Unemployment and Hope." We quote the corresponding section in extenso :—

" 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 rooted 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 unemployment we mean chiefly the unemployed in Great Britain,

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 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 methods which are to remove all the contradictions of a system based on wage labour and individual ownership of the means of production, are a return to those forms of industry which directly preceded the epoch of industrial capitalism.

We have demonstrated above that it is from these very forms that the forward movement of the period of Newton began; and although, by comparison with feudal methods of production, manufacture and small handicraft industry were a step forward, at the present moment the slogan—" Back to small handicraft industry "—is deeply reactionary.

The fetishism of the commodity system, laid bare by Marx's genius, lies in the fact that the relationships of material things. created by human society, are isolated from human relationships and are looked upon as the essence of the things themselves.

The solution and exposure of such fetishism consists in the fact that it is not things which of themselves create relations, but that the relationships between things created in the process of social production simply express the specific social relationships of human beings, which in the latter's view take on the fantastic form of relationships between things.

The views cited above also are a special manifestation of fetishism. Machinery, the means of production, the organisation of production in large-scale machine production are considered in isolation, irrespective of the social relationships of that particular economic system in which the specific method of production exists and by which they were created.

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

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 which transform the worker into a blind tool of mechanism, but those social relationships which so exploit machinery, that the worker merely becomes an accessory.

The way out lies not in the return to the old out-worn method of production, but in the alteration of the whole system of social relationships just as radically as the transition from feudal and handicraft methods of production to industrial capitalism was effected in the past.

Private property passes through stages of development; feudalism, merchant capital and manufacture, industrial capitalism. At every stage of development in the process of production, men, independently of their will, enter into specific production relationships which correspond to the equivalent stage in the development of productive forces. At a certain stage of their development productive forces come into antagonism with the existing production relationships, or, juridically expressed, with the property relationships, within which they developed. From being forms of development the latter become fetters.

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

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 relationships evokes a further turbulent growth of productive forces.

On the contrary, a crisis in the growth of productive forces indicates that their further development within the framework of the given social system is impossible.

And that suggested solution which we cited above, the substance of which consists in the bridling of productive forces by a return to the old forms of production, is only an expression of the contradiction between the productive forces of capitalist society and the production relationships based on private ownership of the means of production.

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

Genuine methods for the transformation of society cannot be found, through brilliant inspiration or guesswork, and not through a return to "the good old times" which in the distant historical perspective appear to be a peaceful idyll, but which in reality represented bitter class struggle and the crushing of one class by another.

Thus it has always been, and so it was in that epoch when

Newton lived and created, in the epoch to whose productive forms we are invited to return.

We have seen that the outworn forms of social relationships of that epoch, speaking through the lips of their University representatives, also recommended the suppression of science, which was shattering the stagnant forms of feudal ideology and was entering the service of new methods of production.

What we are now witnessing is a repetition on a new basis of the fundamental antagonism between productive forces and productive relationships which Marx with brilliant perspicacity discovered and explained.

Whilst the newly emerging proletariat elementally protested by wrecking machines and resisting inventions and science, to-day, armed with Marx', Engel's and Lenin's method of dialectical materialism, the proletariat clearly sees the path towards world freedom from exploitation of man by man.

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

The proletariat exposes all the fetishisms of class society and behind the relationships between articles sees the relationships between the human beings who create these articles.

Having learnt the real nature of the historic process the proletariat does not remain merely a spectator. He 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 a passive, contemplative acceptance of reality, but as a means to effect its active reconstruction.

For the proletariat science is a means and instrument of this reconstruction. That is why we are not afraid to expose the "earthy origin" of science, and its close relations with the methods of production of material existence.

Only such a conception of science can be its real liberator from those fetters with which it is inevitably burdened in class bourgeois society.

Not only does the proletariat not fear the development of productive forces, but it alone can create all the conditions for their unprecedented development, and also for the development of science.

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

And as in all epochs, in reconstructing social relationships we are reconstructing science.

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

The building of socialism not only utilises all the achievements of human thought, but by setting science new and hitherto unknown tasks indicates new paths for its development and enriches the treasures of human knowledge by adding new treasures.

Only in socialist society will science become the genuine possession of all mankind. New paths of its development are opening before it, and there is no limit to its victorious advance, either in infinite space or in everlasting time.

THE PRESENT CRISIS IN THE MATHEMATICAL SCIENCES & GENERAL OUTLINE FOR THEIR RECONSTRUCTION.

By E. COLMAN.