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Monthly Newsletter of Vigyan Prasar

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VP News

Ham Radio Training Prgramme

A training Programme on ham radio has been started at Vigyan Prasar to help interesated persons become hams by clearing the Amateur Radio Station Operator's Certificate examination conducted bythe Ministry of Communications.

The course began on June 01, 2001 and is expected to continue for about six weeks. At present about twenty prospective hams have been taking training and are preparing for the ASOC grade I / II examination . Study materials have been provided to the participants. The programme began without any fanfare. Dr. V. B. Kamble, himself a ham with call-sign VU2VBK, delivered the inaugural talk highlighting the need, utility and importance of ham radio especially during the natural calamities.

A live demonstration was organized by Shri Sandeep Baruah, VU2MUE. Several ham radio stations from different parts of the country provided support for the demonstration. Karan Bakshi VU3GTF (Delhi), Rakesh Kapoor VU2RAK (Delhi), Kumar VU2XD (Delhi), Deb VU2DAD (Akaltara, Chattisgarh), Madan Mohan Prasad VU2MMP (Begusarai, Bihar), and Dipu VU2DPD (Calcutta) were the hams who participated in the demonstration with the NCSTC / Vigyan Prasar ham radio club station VU2NCT. Different modes of radio communication (Morse code, telephony & Computer to Computer) were demonstrated to the participants. Shri D.P. De, VU2DPD from Calcutta responded to the Morse Code call from VU2NCT, and later on voice. Computer to Computer communication through amateur radio was demonstrated with the help of Shri Karan Bakshi, VU3GTF - a young and active amateur radio operator from Delhi. Text messages were exchanged between VU3GTF and VU2NCT's computers.

Inside

VP starts a chat session ....

In our process of popularising Science and Technology, Vigyan Prasar has started a chat session on its homepage "www.vigyanprasar.com" or "www.vigyanprasar.org". This one-hour online interactive chat session is on different popular S&T topics like Health and Medicine, Basic Astronomy, Impact of Pesticides on health, Information Technology, Environment etc. The participants in the chat session can share their views, and know more about the subjects by asking questions on any of the S&T related topics and the experts or specialists in the respective topics will answer the questions.

The first topic of the chat session was "Wonders of the Sky" held on 26th May,2001 at 11.00 a.m.

Our expert in this session was Mr. Biman Basu, editor of popular science magazine "Science Reporter". The participants asked questions related to Astronomy in this session, which were answered by Mr. Basu.

Dr. Yatish Agarwal, doctor and popular health columnist was the expert for our second Chat session on "Health and Medicine" conducted on 9th June, 2001. Similarly, we will have many more chat sessions on S&T topics. The topics and experts will be pre-selected and announced in advance on our homepage from time to time.

We welcome you all to participate in this online chat sessions by logging onto our homepage "www.vigyanprasar.com" and "www.vigyanprasar.org" and get all your queries answered by our experts. Incase you are unable to access our homepage, you can email your queries in advance or immediately after the session to vigyan@hub.nic.in

... think scientifically, act scientifically ... think scientifically, act scientifically ... think scientifically, act...

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Editor : Dr. V.B. Kamble

Predicting the Future

The celebrated British physicist Stephen Hawking was in Delhi on January 17 to deliver the Albert Einstein Lecture 2001. Interestingly, the topic of his lecture was "Predicting the Future: From Astrology to Black Holes". In his characteristic style he said, "the reason most scientists don't believe in astrology is that it is not consistent with our theories which have been tested by experiment". This implies that for a subject to be projected as science, it is necessary to examine whether it follows the scientific discipline by making specific assumption on which it rests. It also follows that the predictions need to be accompanied by tests to prove them right. Indeed, this is how science and society have progressed. Sometimes, the basic ideas or assumptions on which the theory is based, may need to be modified or even discarded when more accurate observations are found to be going against them. An example is the Newtonian gravity. Though highly successful, it was improved upon by Einstein's theory of relativity. There is no gainsaying the fact that a scientific prediction is always characterised by a principle that is provable.

Astrology has been here for centuries, and continues to fascinate the human beings, many of whom even scrupulously regulate their daily activities based on their astrological forecasts. How is it that we wait for the Sunday newspapers for our weekly forecasts? Despite the overwhelming scientific evidence that the positions of the planets and the times of birth do not dictate the course of human affairs, astrology will be with us in the foreseeable future. Why is it so? Given the unpredictable turns in the lives of the individual, often chaotic, most of us long for the comfort of having guidance in making decision. It gives a heady feeling when an astrologer tells us that our personal character and destiny are tied up with the stars – of course for a fee! Further, it is so convenient to blame our failures on cosmic events that are beyond our control! It is this urge to seek correlations between the unpredictable turns in the lives of the individuals and regular movements of the planets that astrology came into being.

Even five centuries after Nikolaus Copernicus, astrologers continue to base their predictions on the assumption that the Earth is at the centre of the universe. In Vedic astrology, the "planets" include the Sun, the Moon, Mercury, Venus, Mars, Jupiter, Saturn and Rahu and Ketu. Incidentally, Rahu and Ketu do not even have any physical existence. Uranus, Neptune and Pluto even after they were discovered, have failed to secure a place in this list. Despite the assumptions at variance with the established knowledge, the horoscopes of individuals are expected to predict their future accurately. Did all those who perished in the recent Gujarat Earthquake have this unfortunate event predicted in their horoscopes? May be, it would be worthwhile instituting a study for the purpose. A famous astrologer states that in astrological predictions what matters is "intuition" – more than anything else. Obviously there is no way to test a theory based on assumptions that are not well-defined or rely on one's intuition alone!

Indeed, astrology has played an important role in the growth and development of human understanding of natural phenomena. The study of planetary motions was prompted by the demands of astrology for determining planetary positions with greater accuracy. Just the way alchemy led to the study of chemistry, astrology led to the study of astronomy. Astrology had its influence on human history as well, the study of which could certainly be relevant and useful.

However, it must be remembered that all scientific disciplines derive their legitimacy from the scientific method, the foundations of which include, a respect for data, consistent reasoning, observational checks and the possibility of experimental refutation. At this juncture one may ask, with an "open mind", if the method or practice of astrology conforms to the method of science.

❑ *V.B. Kamble*

Editor : V.B. Kamble

The team : Vigyan Prasar Staff

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"Planck and the Quantum of Energy"

❑ *V.B. Kamble*

The quantum theory arose out of the inability of the classical physics to explain the experimentally observed distribution of energy in the spectrum of a black body. Although the phenomenon of black body radiation is of relatively minor importance in experimental physics, it is the theoretical attempts to explain the experimentally observed spectrum of the black body radiation that led Max Planck in 1900 to the hitherto unknown and alien idea that, like matter, energy could exist in packets or quanta as he called them. Planck also found that the energy of these quanta was in direct proportion to the frequency (incidentally, quanta is the plural; the singular form is quantum). Following the idea that energy can only be emitted or absorbed in whole quanta, finally Planck could solve the black body puzzle. However, now the theory was based on a hypothesis with no experimental basis! Indeed, it took several years and the efforts of many great scientists to finally establish the quantum theory on a firm footing. Planck's theory proved to be a turning point in the history and conceptual development of modern physics — for which he was awarded the Nobel Prize in 1918. Truly it is a fascinating story and a wonderful account of how a "minor" detail left to be tidied up in the field of thermodynamics turned out to be the origin of the quantum theory. In this article we shall briefly describe the attempts to work out this "minor" detail and how Planck finally solved the puzzle – a golden page from the history of modern science.


Max Karl Ernst Ludwig Planck

Max Planck

Max Karl Ernst Ludwig Planck (1858-1947) was born on October 4, 1858 and was the fourth child of Johann Julius Wilhelm von Planck of Göttingen, professor of civil law at Kiel, and Emma Patzig. In the spring 1867, the family moved from Kiel, where Max had completed the first classes of elementary school, to Munich. His mathematical talents emerged early, and he gratefully recalled his teacher Hermann Müller. Müller's explanation of the principle of conservation of energy made a deep impression on him and this principle became one of the foundations of Max Planck's later work. He graduated from Königliche Maximilian – Gymnasium in 1874. As a child he had displayed considerable ability in music. He was an excellent performer on the piano and organ. Planck was prepared in principle to study the mathematic disciplines, or music, or even classical philology – the science of language especially in its historical and comparative aspects. Philology attracted him because of its grammatical and moral harmony. He probably gave up his musical career when, on seeking advice from a professional musician, he was told: "If you have to ask, you would better study something else!" Nevertheless music remained a life-long hobby for Planck. He was attracted to physics despite having been advised that nothing essentially remained to be discussed in this branch of learning.


Wilheln Wien

Because of illness, he had to interrupt his studies during the summer term of 1875. He went to the University of Berlin for the winter semester of 1877-1878 and the summer of 1878. There he heard, in addition to the lectures of Weierstrass, those of Kirchhoff and Helmholtz, although he was not convinced that he learned very much from the latter two. By himself he studied Clausius' *Mechanische Wärmetheorie* in detail and later remarked that this private study was what had finally drawn him into physics. These investigations led him to the preparation of his doctoral dissertation on the second law of thermodynamics, for which he was awarded the Ph.D. degree at the University of Munich on 28 July 1879. An appointment as professor extraordinarius at the University of Kiel on 2 May 1885 gave Planck greater scientific independence. Positions of this kind were then rather new in Germany and were restricted primarily to theoretical physics, which did not have a very high status compared to experimental physics. It seems that, as a result, Planck had relatively few students and so had correspondingly more time available for research in his new subject.

Planck was appointed on 29 November 1888 to be the successor of Kirchhoff, as assistant professor at the University of Berlin and director of the Institute for Theoretical Physics (Newly founded for him). He served as professor ordinarius in Berlin from 23 May 1892 to 1 October 1926. He quickly attained professional recognition; he was at once made a member of the Physikalische Gesellschaft zu Berlin and was elected to the Königlich-Preussische Akademie der Wissenschaften zu Berlin on 11 June 1894. His circle of colleagues included such men as Herman von Helmholtz, Ernst Pringsheim and Wilhelm Wien. The bulk of Planck's work may be divided into thermodynamics, radiation theory, relativity, and philosophy of science.


Albert Einstein

Planck received the high distinction of the 1918 Nobel Prize in Physics, but his personal life was clouded by misfortune. His first wife died on 17 October 1909, his son Karl during World War I (1916), and his two daughters Margarete and Emma during childbirth (1917 and 1919). His older son from this marriage was executed in 1944 on suspicion of conspiracy to assassinate Adolf Hitler. On 14 March 1911 Planck married the niece of his first wife, Marga von Hoesslin; they had one son, Hermann.

Planck lived through two world wars, and his correspondence with Lorentz, Schweitzer, and others shows that he maintained an uncorrupted independent viewpoint and a positive attitude towards life. In 1944 almost all his manuscripts and books in Berlin were destroyed during an air raid. From 1943 to 1945 he lived in Rogätz, near Magdeburg, and then for the last two and a half years of his life he was in Göttingen, where he witnessed the founding of the Max Planck Gesellschaft zur Förderung der Wissenschaften, successor to the Kaiser Wilhelm Gesellschaft founded in 1911. (He had been its president from 1930 to 1937).

Incidentally, Planck achieved his doctorate by a thesis on an experiment in the diffusion of hydrogen through palladium. This was the only experiment he ever performed: one may suspect that it was imposed on him rather than chosen by him. Even before he won his doctorate, he had devoted himself to the theoretical study of the foundations of thermodynamics. He saw rather more deeply into the second law of thermodynamics than anyone before him, and his textbook on thermodynamics is still a classic.

Explaining the Physical World

At some stage or the other, all of us have wondered – how our universe came to be so rich and varied? Often we have wondered how the stars, light, planets, and a hundred different atoms that can be combined into countless molecules. Elementary particle physicists seek answers to these questions by studying sub atomic particles and forces. A century ago, the first elementary particle – the electron – was identified. A revolutionary view of the way matter in the universe is put together was provided by the experimental evidence that electrons were basic constituents of all atoms. Quantum Mechanics explained the paradoxical motion of electrons in the atom and the formation of molecules. Eventually, a vast range of phenomena – the stiffness of steel, the way petrol burns, colours in the surface of the bubble, the ability of X-rays to reveal tumours inside the body – could be accounted for by the quantum mechanical behaviour of the electron. This new perspective, a view of the world on more fundamental scale than the everyday world of our experience, eventually led to a century of spectacular science and technological innovation. Understanding the behaviour of the electron and photon, i.e., the quantum of light, has been critically important to the fields of chemistry, materials science, and biology, as well as to the development of modern computing and communication.

It was by way of thermodynamics that Planck came to the quantum theory. Thermodynamics is a hard subject, and Planck arrived at the quantum theory by the hard way. When he entered upon thermodynamics, it was a science of heat in matter. **Planck extended it to light.**

The Cavity Problem

Imagine a cavity inside a solid body. There is a small perforation in the wall of the cavity, out of which light can come. It must be large enough so that we can get enough light out of it to analyze with a spectroscope; it must also be small enough so that the light which comes out will be a fair sample of what the light inside would be if the perforation were not there. We have therefore to assume that one and the same perforation can be neither too large nor too small.

First let us suppose that there is some gas inside the hollow. For definiteness let the gas be helium, which is a monatomic gas and nearly a perfect gas. The gas has energy, which is the kinetic energy of its atoms. This kinetic energy we know to be proportional to the absolute temperature. We also know that the energy is proportional to the number of atoms. If we pump half of the gas out of the cavity while the temperature remains the same, the energy of the gas in the hollow is reduced to one-half; if we pump extra helium into the cavity so as to double the quantity, we double the energy.

Let us now imagine that all the gas is pumped out. The cavity is still not empty, for it still contains light, in fact, just the same amount of light as while the gas was there. Since the cavity contains light, it contains the energy of that light. This energy is proportional, however, not simply to the temperature but to the *fourth power* of the temperature. There is also a much more important difference between light and helium: namely, whereas the energy of the helium in the cavity is proportional both to the absolute temperature and to the amount of helium, the energy of the light depends only on the temperature. There is no point in saying that the energy of the light is proportional to the amount of light, for the amount cannot be varied. There is no pump by which we can pump out half of the light and leave the rest. We could indeed increase the amount of light in the hollow by shining a searchlight through the perforation, but this would make no lasting difference. The beam of the searchlight would be absorbed in the walls of the cavity and heat them up; as soon as we turned off the searchlight, the temperature would start to revert to its original value, and when it got back to its initial value there would be the same amount of light in the cavity as before.

The light emerging through the perforation has a perfectly distinctive spectrum, and this we have assumed to be identical with the spectrum of the light inside the cavity. As we shall see later, on a graph in which energy is plotted against frequency, the spectrum has single broad hump, meaning that the energy is greatest at the middle wavelengths in the spectrum and least at the highest and lowest frequencies. People usually call it the "black body spectrum", because a perfectly black body would emit light of this composition. It seems paradoxical that a black body should emit light, but it is no paradox at all when we remember the distinction between emission and reflection. The practical definition of blackness is that it is the quality of not reflecting light. A black body does not reflect, but it may emit; in fact, it is the most powerful possible emitter of light. We ordinarily look at bodies–black, white or coloured–when they are reflecting light but are not hot enough to emit an appreciable amount of visible light. At temperatures of incandescence, a black body would look brightest of all, for example our Sun.

Black Body Radiation

As remarked earlier, a black body, is one that absorbs all frequencies of light and reflects not even the slightest little shimmer. A piece of coal is a good approximation. So is the coil of room heater. A black body, when heated, would also emit radiation better than anything else. In other words, a black body which is the most efficient


Niels Henrik David Bohr


Arthur Holly Compton


Prince Louise-Victor Pierre Raymond deBroglie

absorber, is also the most efficient radiator. It is interesting to note that every body at a temperature greater than absolute zero emits thermal radiation. (Incidentally, the so called absolute or Kelvin temperature written is °K, is obtained by adding 273.15° to the centigrade (or Celsius) temperature, i.e. °K = °C + 273.15°). But, why should any body at a temperature greater than the absolute zero emit this radiation?


Werner Karl Heisenberg

In the classical theory, this can be pictured as the result of the accelerations of electric charges near the surface due to thermal agitation. Now, in a single acceleration lasting for a certain period of time, most of the emitted radiation has a frequency approximately equal to the reciprocal of the period, and a wavelength equal to *c* times the period, where c is the velocity of light. But, in the many different acceleration processes which give rise to the thermal radiation, a whole spectrum of wavelengths is emitted. On the basis of this picture, it would be expected that the rate of emission of energy, integrated over the entire wavelength spectrum, would increase as the temperature of the surface increases because of the enhanced thermal agitation, and it would also be expected that the rate of emission of energy would be proportional to the area of the surface. This is found to be the case; an empirical equation due to Stefan (1879) states


Irwin Schrodinger

$$I_T = \sigma e T^4$$

The quantity I_T is the total energy emitted in all frequencies per second per cm^2 from a surface at absolute temperature T; e is a constant called the *emissivity* which ranges from 0 to 1 depending on the nature of the emitting surface; and $\sigma = 0.567 \times 10^{-4}$ erg-cm^{-2}-deg^{-4}-sec^{-1} is the Stefan-Boltzmann constant. The energy emitted as thermal radiation is supplied by the thermal agitation energy. For a black body e=1.


Paul Adrien Maurice Dirac

We can now see that the radiant power emitted per cm^2 is the same for *all* black bodies which are at the *same* temperature. This suggests that other properties of the thermal radiation emitted by the black bodies, such as the spectral distribution of the radiation, i.e. distribution of energies emitted at different frequencies (or wavelengths), also depend *only on the temperature of the black body but not its detailed nature.*

The Black Body radiation at different temperatures

Let us have a look at how the black body radiation at different temperature looks like. The spectral distributions of black body radiation is specified by the quantity $I_T(\lambda)$, which is so defined that $I_T(\lambda)\,d\lambda$ is equal to the energy emitted per

A Long Journey

Quantum theory has helped us unravel the natural processes at atomic and sub-atomic levels and push the frontiers of our knowledge further and further. Understanding the properties of fundamental particles and the nature of forces in the sub-atomic level could become possible only with the application of quantum mechanics. Let us briefly see where quantum theory has led us to during the last hundred years.

Particle physicists zoomed in on the sub-atomic realm with increasingly powerful instruments. Forces were revealed in the sub-atomic level that no one had predicted, the best example being the strong nuclear force that holds the atomic nucleus together. Experiments revealed the existence of hundreds of different and unexpected particles. Eventually patterns emerged and theories were put together and tested. Today, elementary particle physics provides the basis for understanding an astonishing variety of phenomena in terms of just a few "truly" elementary particles and forces between them.

The remarkable state of our understanding of elementary particles, embodied in the present theory called the "Standard Model," has taken shape over the last 30 years. The Standard Model provides an organizing framework for the known elementary particles. These consist of "matter particles," which are grouped into "families," and "force particles." The first family includes the electron, two kinds of quarks (called "up" and "down"), and a neutrino, a particle released when atomic nuclei undergo radioactive decay. There are two more families consisting of progressively heavier pairs of quarks and a corresponding lepton and neutrino. All normal, tangible matter is made up only of particles from the first family, since the others live for very short times. Why are there three families? This question is one of the great unsolved mysteries of elementary-particle physics.

The matter particles exert forces on one another that are understood as resulting from the exchange of the force-carrying particles, Electric and magnetic forces arise when particles exchange quanta of light or photons (the familiar repulsion or attraction of two magnets results from one of them emitting photons that the other receives). The strong force that holds quarks together to form protons and neutrons comes from the exchange of gluons. The weak forces that cause radioactive decay are created by massive W and Z particles (the photon and gluon have no mass). These three forces have been successfully described by quantum theories that have remarkably similar structures.

Theories have recently been developed that link elementary particles, the very smallest known structures, with one of the grandest questions of all: How did the universe begin? These theories suggest that many of the complexities manifest at lower energies would be greatly simplified under conditions of extremely high energy. For example, under such conditions the different forces between the particles would be seen as unified, different manifestations of a single underlying force. There is nothing artificial about these energies: They are understood to have prevailed at the time of the "big bang" that initiated the expansion of the universe. If these theories are correct, the simplicity long sought by particle physicists is a fact of cosmic history.

Although re-creating these energies lies beyond the reach of existing and planned accelerators, experiments at these accelerators could nonetheless reveal evidence for what is called supersymmetry. Supersymmetry, which is really a very profound statement about the structure of space and time, predicts that for every fundamental particle there should exist another related and as yet-undiscovered new particle; conclusive evidence for these additional particles is eagerly sought because supersymmetry shows how the electroweak and strong interactions could be unified.

In addition, evidence of supersymmetry would also support another even more comprehensive theory, called string theory. String theory pictures particles as extremely tiny vibrating loops, with details of their vibrations determining their properties and interactions, and leads to a theory that is able to encompass ALL of the forces of nature in a unified and self-consistent manner, including – for the first time – gravity. A long journey indeed since the birth of the quantum!

second, in radiation of wavelength in the interval λ and $\lambda+d\lambda$, from 1 cm² of a surface at temperature T. The names Lummer and Pringsheim are associated with the earliest accurate measurements of this quantity (1899). The measurements were made with an instrument essentially similar to the prism spectrometers used in measuring optical spectra, except that special materials had to be used to have the lenses, prisms, etc. transparent to the long wavelength thermal radiation. The observed dependence of $I_T(\lambda)$ on λ and T is indicated in Figure 1. The arrow on the abscissa indicates the wavelength at which the eye has its maximum response (green light).

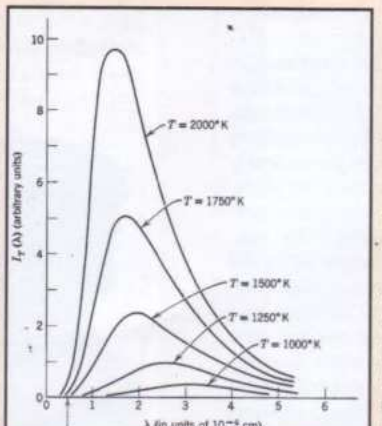


Fig. 1 : The spectral distribution of black body radiation at several temperatures

We see that, for any fixed $\lambda I_T(\lambda)$ increases with increasing T. The integral of $I_T(\lambda)$ over all λ is, of course, just equal to the quantity I_T previously defined. This integral, which is equal to the area under the curves, does increase with the fourth power of T, in agreement with Stefan's law. Figure (1) also shows that the spectrum shifts towards shorter wavelength as T increases. A quantitative inspection of the figure will demonstrate the validity of the equation

$\lambda_{max} \propto 1/T$ *or*

$\lambda_{max} T = constant$

where λ_{max} is the λ at which $I_T(\lambda)$ has its maximum value for a particular T. *This is known as the Wien's displacement law.* All these results are in agreement with the everyday experience that bodies emit more heat as their temperature increases, and that with increasing temperature their "colour" shifts from dull red to blue white (i.e. increasingly more radiant energy is emitted in the region of short wavelength). It may be worth noting that Wien's displacement law allows us to infer the temperature of a body (or a star) once the λ_{max} is known through the study of the spectrum emitted by it.

Clinton Joseph Davisson

George Paget Thomson

Wolfgang Pauli

Now consider an object containing a cavity which is connected to the outside by a small hole (Figure 2). Radiation incident upon the hole from the outside enters the cavity and is reflected back and forth by the walls of the cavity, eventually being absorbed on these walls. If the area of the hole is very small compared with the area of the inner surface of the cavity, a negligible amount of the incident radiation will be reflected back to the hole. Then all the radiation incident upon the hole is absorbed. For the hole, absorptivity or the ratio of energy absorbed to the total energy incident per unit area, a = 1 and therefore the hole must have the properties of the surface of a black body.

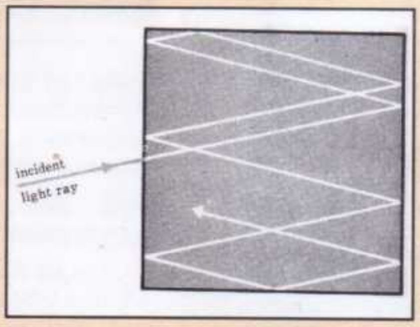


Fig. 2 : A hole in the wall of a hollow object is an excellent approximation of a black body

Next assume that the walls of the cavity are uniformly heated to a temperature T. The walls will emit thermal radiation which will fill the cavity. The small fraction of this radiation incident from the inside upon the hole will pass through the hole. Thus the hole will act as an emitter of thermal radiation. Since the hole must have the properties of the surface of a black body, the radiation emitted by the hole must have a black body spectrum. But, *as the hole is merely sampling the thermal radiation present inside the cavity, it is clear that the radiation in the cavity must also have a black body spectrum.*

Wien's Law

We can understand many of the properties of black body radiation from the classical theory of thermodynamics. In 1884 Boltzmann produced a theoretical derivation of the equation giving I_T the total energy emitted per cm² per second, for a black body radiator (Stefan's Law for the case e=1). In this derivation he considered a cavity with reflecting walls in the form of a cylinder with a movable piston and filled with thermal radiation at temperature T. Thermal radiation, in common with all other electromagnetic radiation, can be shown to exert a pressure proportional to its energy density. In this respect it behaves just like a gas. Taking this system through a cycle of expansion and compression, called in thermodynamics a Carnot cycle, Boltzmann obtained a relation between the work done by the pressure of the radiation, and its temperature. This relation leads to the desired result since the pressure can be expressed in terms of the energy density, which can in turn be expressed in terms of I_T.

In the process of expansion or compression of such a cavity filled with radiation, the wavelength of any spectral component of the radiation will be changed as the result of a Doppler shift upon reflection from the moving piston in the same way the whistle from a railway engine approaching us sounds shrill (i.e. an apparent increase in its frequency) or flat while receding away from us (i.e. an apparent decrease in its frequency). From a detailed consideration of this fact, Wien (1893) was able to derive a general functional form for the spectral distribution of black body radiation known as *Wien's law:*

$$\rho_T(\lambda) = \frac{f(\lambda T)}{\lambda^5}$$

where $f(\lambda T)$ is some function of the product of the wavelength and the temperature, whose form is not specified by Wien's derivation. $\rho_T(\lambda)$ is the energy density defined such that $\rho_T(\lambda)\,d\lambda$ is the energy contained in cm³ of the cavity in the wavelength interval λ to $\lambda+d\lambda$. This equation is in excellent agreement with the experimental data, as can be seen from Figure 3. This figure plots λ^5 times $\rho_T(\lambda)$ as a function of λT, using 1259° K, 1449°K, and 1646°K data of Lummer and Pringsheim for $I_T(\lambda)$ [which is proportional to $\rho_T(\lambda)$]. We see that all sets of data fall on the same smooth curve, confirming the prediction of Wien's Law that $\lambda^5 \rho_T(\lambda)$ is equal to a universal function of the variable λT. It is apparent that Wien's law agrees with the empirical fact expressed by equation $\lambda_{max} \propto 1/T$.

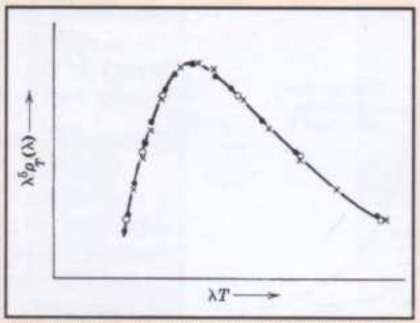


Fig. 3 : An experimental verification of Wien's Law (at T=1646°K; T = 1449°K; and T=1259°K)

The Rayleigh-Jeans Theory

Wien's thermodynamical derivation performed the useful role of allowing all black body spectra measured at different temperatures to be discussed theoretically in terms of the single function f (λT). **But the derivation did not evaluate the form of this function.** It is typical of a thermodynamical argument to show that certain relations must obtain between the variables which describe some physical system, but not to provide a complete theory of the behaviour of the system. The reason is that such arguments are based on general principles that apply to all physical systems, but do not involve the details of the composition of the particular system in question. A theory which would be able to evaluate the function f (λT) must take into account some of the detailed properties of a black body as well.

Max Born

S.N. Bose

Chen Ning Yang

Consider a cavity with metallic walls at temperature T. The walls emit thermal electromagnetic radiation. In thermal equilibrium this radiation has a black body spectrum characteristic of the temperature T. Furthermore, in the steady state attained at equilibrium the electromagnetic radiation inside the cavity must exist in the form of standing waves with nodes at the metallic surfaces. Rayleigh and Jeans calculated the number of standing waves with nodes at the surfaces of the cavity in the wavelength interval λ to $\lambda + d\lambda$. They then calculated the average energy of these waves. The energy depends on the temperature T and is evaluated from the theory of statistical mechanics. The number of standing waves in the wavelength interval times the average energy of the waves divided by the volume of the cavity is equal to the average energy per cm³ in the wavelength interval λ to $\lambda + d\lambda$, which is just $\rho_T(\lambda)$. From this f (λT) is evaluated by using equation $\rho_T(\lambda) = f(\lambda T)/\lambda^5$

Planck's postulate and simple pendulum

The success of Planck's postulate in leading to a theoretical black body spectrum which agrees with experiment requires that we tentatively accept its validity, at least until such time as it may be proved to lead to conclusions which disagree with experiment. Apparently, there are physical systems whose behavior seems to be obviously in disagreement with the postulate. For instance, an ordinary pendulum executes simple harmonic oscillations, and yet this system certainly appears to be capable of possessing a continuous range of energies. Before we accept this argument, it would be desirable to make some simple numerical calculations concerning such a system. Consider a pendulum consisting of a 1gm weight suspended from a 10cm string. The oscillation frequency of this pendulum is about 1.6/sec. The energy of the pendulum depends on the amplitude of the oscillations. Assume the amplitude to be such that the string in its extreme position makes an angle of 0.1 radian with the vertical; then the energy E is approximately 50 ergs. If the energy of the pendulum is quantized, any decrease in the energy of the pendulum, due for instance to frictional effects, will take place in discontinuous jumps of magnitude $h\nu = 6.63 \times 10^{-27} \times 1.6 \simeq 10^{-26}$ ergs, whereas $E \simeq 50$ ergs, it is apparent that even the most sensitive experimental equipment would be totally incapable of resolving the discontinuous nature of the energy decrease.

No evidence, either positive or negative, concerning the validity of Planck's postulate is to be found from experiments involving a pendulum. The same is true of all other macroscopic mechanical systems. Only when we consider systems in which $h\nu$ is of the order of E are we in a position to test Planck's postulate.

If we assume a metallic walled cavity filled with electromagnetic radiation in the form of a perfect cube of edge length a, then the number of allowed frequencies N (ν) in the frequency interval ν to $\nu + d\nu$ is given by

$$N(\nu)\, d\nu = \frac{8\pi a^3 \nu^3\, d\nu}{c^3}$$

It can be shown that $N(\nu)\, d\nu$ is independent of the assumed shape of the cavity and depends only on its volume a^3.

The next step in the Rayleigh-Jeans calculation was the evaluation of the average energy contained in each standing wave of frequency ν. According to classical physics, the *particular energy* of some wave can have *any value* from zero to infinity; the actual value is proportional to the square of its average amplitude. But, if we have a system containing a large number of physical entities of the same kind which are in thermal equilibrium with each other at temperature T, such as the system of standing waves in equilibrium in the black body cavity, the classical theory of statistical mechanics demands that the energies of these entities be distributed according to a definite probability distribution whose form is specified by T. As the *average energy* is determined by the probability distribution, it must have a *definite value* that depends on T. It turns out that the average energy per standing wave is given by kT, where $k = 1.38 \times 10^{-16}$ erg - deg⁻¹ is Boltzmann constant.

The energy per cm³ in the frequency interval ν to $\nu + d\nu$ of the black body spectrum of a cavity at temperature T is just the product of the average energy per standing wave (kT) and the number of standing waves in the frequency interval divided by the volume of the cavity. That is,

$$\rho_T(\nu)\,d\nu = \frac{8\pi\nu^2 kT\,d\nu}{c^3}$$

To make a comparison with our earlier discussion, we must express the energy density in terms of the wavelength λ. This can be done by using the relation $\nu = c/\lambda$. It now can be easily shown that

$$\rho_T(\lambda)\,d\lambda = \frac{8\pi k\lambda T\,d\lambda}{\lambda^5}$$

This is the Rayleigh-Jeans spectral distribution of black body radiation.

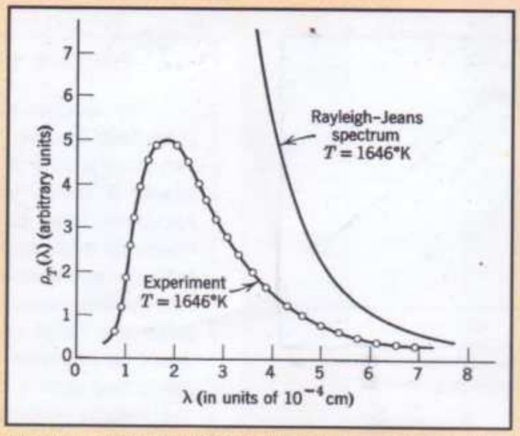


Fig. 4 : A comparison of the Rayleigh-Jeans spectrum and experiment

We note that it has the form required by Wien's law since it can be written $\rho_T(\lambda) = f(\lambda T)/\lambda^5$, where $f(\lambda T) = 8\pi k\lambda T$. However, as is seen in Fig.4, the Rayleigh-Jeans spectrum is in complete disagreement with the experimental data; it predicts the wrong form for the function $f(\lambda T)$. In the limit of long wavelength, the Rayleigh-Jeans spectrum approaches the experi-mental results. But as $\lambda\rightarrow 0$, their theory predicts that $\rho_T(\lambda)\rightarrow\propto$, whereas experiment shows that $\rho_T(\lambda)$ always remains finite and is equal to zero at zero wavelength. The unrealistic behaviour of the Rayleigh-Jeans distribution at short wavelengths is known in physics as the **"ultraviolet catastrophe"**. This terminology is suggestive of the importance of the failure of the Rayleigh-Jeans theory. Let us evaluate the total energy per cm³ for the Rayleigh-Jeans spectrum:

Tsung-Dao Lee

Eugene Paul Wigner

Sin-Itiro Tomonaga

$$\int_0^\infty \rho_T(\lambda)\,d\lambda = 8\pi kT\int_0^\infty d\lambda/\lambda^4 = \frac{8\pi kT\,[\lim \lambda\rightarrow 0\,(1/\lambda^3)]}{3}$$

This goes to infinity unless T=0. *We have here an even more impressive indication of the complete failure of the Rayleigh-Jeans spectrum. Yet this spectrum is, as we have mentioned earlier, a necessary consequence of the theories of classical physics.*

The "ultraviolet catastrophe" was one of the "**minor**" details to left to be tidied up in the field of thermodynamics. What the Rayleigh-Jeans formula implies broadly is that the number of frequencies in the high frequency range to be far greater than the number of frequencies in the low frequency range since high frequencies have shorter wave lengths and more could be packed into the black body. So the problem with blackbody radiation is that, if a body radiates all frequencies equally, the number of radiations in the high frequency range should vastly outnumber those in the low frequency range. In fact, almost all the radiation should be high frequency — that is, at the ultraviolet end of the spectrum. **But, that does not happen!** And no one could explain why in term of physical theory in the 1890s, although several people had tried hard.

Julian Schwinger

Richard P. Feynman

Enter Planck

Max Planck wasn't the type to start a revolution. Tall and spare, quiet and dignified — some said "stuffy and pedantic" — he was completely devoted to tradition and authority, both in his physics and in his life. His work was competent but promised nothing special. For his doctoral work he chose thermodynamics because he admired Clausius's work in the same field, but there was little in his dissertation to excite anyone's attention; to all outward indications he was headed straight for a largely uninspired and mediocre career. Even after securing a professorial appointment at the University of Berlin in 1889, Planck appeared to be travelling pretty much on the beaten path. Certainly his choice of thermodynamics as his specialty didn't promise much in the way of major achievements.

He spent more than six years of his life trying to find a solution to the black body radiation problem. And after he found it, physics would never be the same again. For, in quietly solving the puzzle of blackbody radiation, Max Planck discovered a key principle that, followed up by others, would forever change our understanding of the world.

As one science historian put in, "Planck was like a man who, before the discovery of fire, wanted to find the best ways to bore holes, who for months, years, even decades, bored holes in every material he could find in every conceivable fashion and in doing so chanced to discover fire".

Based on hunch, in 1900 Planck worked out a simple equation describing the distribution of radiation accurately over the entire stretch of frequency. His basic premise went like this: What if energy is not infinitely indivisible? What if, like matter, energy exists in particles or packets, or *quanta*, as he called them — from the Latin interrogative adjective meaning "How much?" Planck also found that the size of these quanta was in direct proportion to the frequency. So radiation at low frequencies is easy — it requires only small packets or quanta of energy. But for a frequency twice as high, radiation would require twice the amount of energy.

The discrepancy between experiment and theory was resolved in 1901 by Planck — but only at the expense of introducing a postulate which was not only new, but also drastically at variance with certain concepts of classical physics.


Murray Gell-Mann


Sheldon Lee Glashow

Planck set out to explain the black body spectrum. He postulated that all solid bodies, and therefore the walls of the cavity, contained little oscillators – he called them resonators – of every imaginable frequency. By resonators Planck meant small electrified particles which wiggled to and fro. It followed that in any range of frequencies, however narrow, there must be resonators having frequencies in that range. Take, for instance, the bright yellow spectrum-line of sodium which is designated by the letter D. We are to imagine, that there are resonators having frequencies within this narrow range. All of them are emitting yellow light into the cavity, and yellow light is coming right back out of the cavity and bathing them and stimulating them to continued oscillation. There is an equilibrium between the energy of the resonators and the energy of the yellow light. So it is with the energy of blue light and the resonators which have the frequency of blue light, and so it is throughout the entire spectrum. If by any valid line of reasoning one could arrive at the energy which the resonators of any frequency have when they are in equilibrium with the light, one would be able to arrive by one simple further step at the energy which the light of any frequency has when it is in equilibrium with the resonators. This would be the answer to Planck's question, for it would give the black body spectrum.

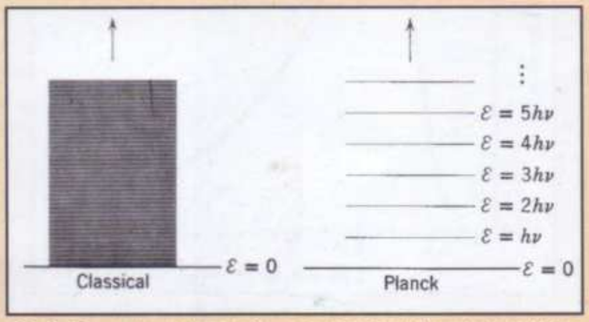


Fig. 5 : Energy Level diagram for a classical simple harmonic oscillator and a simple harmonic oscillator obeying Planck's postulate

There was an answer to this question before Planck, but the answer was a disaster, as we shall soon see. This "classical" answer was that all the resonators have the same energy, no matter what their frequency. From this it followed that the quantity of light in the cavity would be infinite, and since the quantity of light in the cavity actually is finite, the theory was sunk.

The flaw in the classical theory lay in one of its assumptions – indeed, a very plausible one – to wit: that any resonator may have any amount of energy; in other words, that it may go continuously up or down the energy-scale through all levels, like a man walking up or down a ramp. **Planck replaced the ramp by a ladder, with its rungs, as in any practical ladder, at equal intervals.** His assumption was that the resonator must always be on one or another of the rungs, and if it proceeds up or down the ladder, it must proceed by jumping from rung to rung. That is to say, it may absorb or emit energy only in certain discrete units, represented by the equal spacing from rung to rung of the ladder. **Planck then affirmed that the spacing between the rungs of the ladder was not the same for all resonators but must be proportional to the frequency of the resonator in each case.** He designated the spacing, or energy unit, as hν, and said that h is a universal constant, ν being the frequency of the resonator.

Planck's substitution of the ladder for the ramp not only avoided the disaster of infinity but yielded the actual from the black body spectrum. Let us see how.


Abdus Salam


Steven Weinberg

The Quantum Postulate

Planck's postulate may be stated as follows:

Any physical entity whose single "coordinate" executes simple harmonic oscillations (i.e. is a sinusoidal function of time) can posses only total energies e which satisfy the relation

$\varepsilon = nh\nu, \; n = 0, 1, 2, 3, \ldots..$

where ν is the frequency of the oscillation and h is a universal constant.

We may note here that the word "coordinate" is used in its general sense to mean any quantity which describes the instantaneous condition of the entity. Examples are: the length of a coil spring, the angular position of a pendulum bob, the amplitude of a wave. All these examples happen also to be sinusoidal functions of time.

An energy level diagram (Figure 5) provides a convenient way of illustrating the behaviour of an entity governed by this postulate, and it is also useful in contrasting this behaviour with what would be predicted by classical physics. In such diagrams we indicate each of the possible energy states of the entity with a horizontal line. The distance from the line to the zero energy line is proportional to the total energy to which it corresponds. Since the entity may have any energy from zero to infinity according to classical physics, the classical energy level diagram consists of a continuum of lines extending from zero up. However, the entity executing simple harmonic oscillations can have only one of the discrete total energies $\varepsilon = nh\nu$, n = 0, 1, 2, 3, ..., if it obeys Planck's postulate. This is indicated by the discrete set of lines in its energy level diagram. The energy of the entity obeying Planck's postulate is said to be *quantized*, the allowed energy states are called *quantum states,* and the integer n is called *quantum number*.

Let us recalculate $\rho_T(\lambda)$ under the assumption that Planck's postulate is obeyed by the electromagnetic standing waves whose amplitudes are executing simple harmonic oscillation with frequency ν. No modification will be required in the calculation of N (ν) dν since at no point in that calculation was it necessary to specify the energy of the standing waves. The calculation of the average energy ε however will need to be redone since under Planck's postulate, ε can only have the discrete values nhn, where n = 0, 1, 2, 3, ..., while in classical physics it could assume any value. It turns out that the average energy using Planck's hypothesis is given by $h\nu/(e^{h\nu/kT}-1)$ rather than kT as given in classical physics.

Evaluating $\rho T(\nu)$ dn as in the case of Rayleigh-Jeans theory, we obtain

$$\rho_T(\nu)\,d\nu = \frac{8\pi\nu^2 h\nu\, d}{c^3\, e^{h\nu/kT}-1}$$

In terms of the variable λ, it would read

$$\rho_T(\lambda)\,d\lambda = \frac{8\pi hc \quad d\lambda}{\lambda^5\, e^{hc/k\lambda T}-1}$$

This is the black body spectral distribution derived by Planck that marked the beginning of the Quantum Theory. It satisfies Wien's law with $f(\lambda T) = (8\pi hc/\lambda^5)\,[1/(e^{hc/k\lambda T}-1)]$. This function involves the constant h whose numerical value is to be determined by fitting the theoretical spectrum to the experimental data. Such a fit is shown in figure 6. The value providing the best fit to the data is $h = 6.63 \times 10^{-27}$ erg-sec

The constant h is known as Planck's constant. Its value must be determined by experiment; it is not prescribed by theory. It has been measured in a variety of ways, and all of the measurements agree. Planck may be characterized as the man who put h into physics. The figure shows that Planck's theoretical spectrum is in extremely good agreement with the experimental spectrum for T=1646°K. Since it satisfies Wien's law, we know that it will agree equally well with experiment at any other temperature.

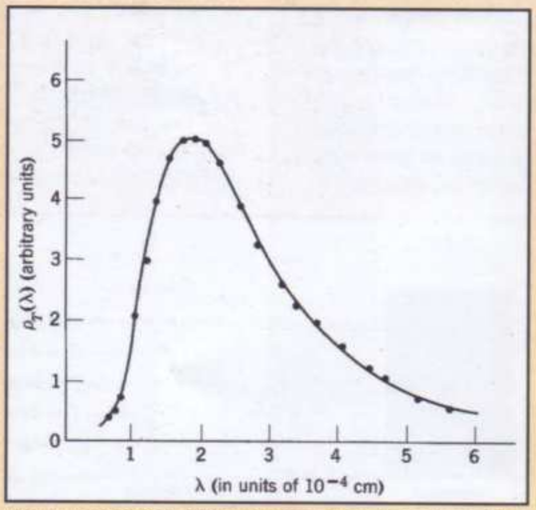


Fig. 6 : A comparison of Planck's spectrum and experiment. The dots are experimental and the curve is theroretical. T= 1646°K

Why does Planck's postulate reproduce the black body spectrum?

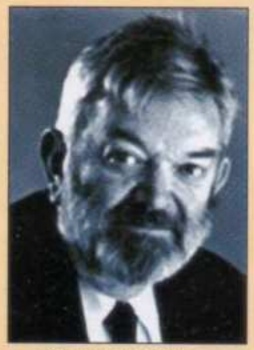
The failure of the Rayleigh-Jeans theory is really due to the rapid increase in $N(\nu)\,d\nu$ as ν becomes large. Since the classical law of equipartition of energy requires that ε be independent of ν, the spectrum itself will also increase rapidly with increasing ν (or decreasing λ). Planck's postulate has the effect of putting a cut-off into ε so that it does not obey the classical law. This keeps the spectrum bounded and, in fact, brings the spectrum to zero as $\nu \rightarrow \infty$ (or as $\lambda \rightarrow 0$). It can be shown that for ν large enough (λ small) so that hν is quite large compared to kT, the average energy for the standing wave is negligible and close to zero, and has the effect of overcoming the "ultraviolet catastrophe". On the other hand, for very low frequency standing waves (large λ) in which hν is quite small compared to kT, the quantum states are so close together that they behave as if they were continuously distributed as in the classical theory. Thus in the low frequency limit Planck's value of average energy approaches the classical value of average energy, i.e. equal to kT, and the spectrum predicted by Planck's theory and that predicted by Rayleigh-Jeans theory approach the experimental spectrum.

Gerardus 't Hooft

Quantum Theory – A Turning Point

Planck had solved the blackbody puzzle, but once it was laid out before him with all of its full implications he wasn't happy with the final picture he saw. He didn't want to see classical physics destroyed, and the quantum theory would do that. Still, he knew that he had started something that could not be stopped. The power of the theory was too great, even if its implications were frightening to him. "We have to live with quantum theory", he concluded, "And believe me, it will expand ..... It will go in all fields". Max Planck, though, was not the one who would push it into those fields. For the rest of his life he would be famous for discovering the quantum, but he would spend his working days trying somehow to reconcile his disturbing discovery with his beloved classical physics. It was an attempt bound to fail. "My vain attempts to somehow reconcile the elementary quantum with classical theory continued for many years, and cost me great effort", he wrote near the end of his life, "Many of my colleagues saw almost a tragedy in this, but I saw it differently because the profound clarification of my thoughts I derived from this work had great value to me. Now I know for certain that the quantum of action has a much more fundamental significance than I originally suspected".

Sure enough, within five years of Planck's theory of black body radiation, in 1905, Einstein examined the photoelectric effect and proposed a quantum theory of light explaining the phenomenon. The photoelectric effect is the release of electrons from certain metals or semiconductors by the action of light. He realised that Planck's theory made implicit use of the light quantum hypothesis. In 1913, Niels Bohr wrote a revolutionary paper on the hydrogen atom and discovered the major laws of the spectral lines. Arthur Compton derived relativistic kinematics for a scattering of a photon (a light quantum) off an electron at rest in 1923. The year 1924 saw the publication of another fundamental paper. It was written by Satyendranath Bose and rejected by a referee for publication. Bose then sent the manuscript to Einstein who immediately saw the importance of Bose's work and arranged for its publication. Bose proposed different states for the photon. He proposed that there is no conservation of the number of photons. Instead of statistical independence of particles, Bose put particles into cells and talked about statistical independence of cells. Time has shown that Bose was right on all these points.



Martinus J.G. Veltman

Work was going on at almost the same time as Bose's which was also of fundamental importance. The doctoral thesis of Louis de Broglie was presented which extended the particle wave duality for light to all particles, in particle to electrons. Schrodinger in 1926 published a paper giving his equation for the hydrogen atom and heralded the birth of wave

Nobel Prizes awarded for work with Quantum Theory and/or its application.

The quantum theory brought about a sea change in our conceptual understanding of phenomena observed at atomic level. Here is a list of Nobel Prizes awarded for work on quantum theory and/or its applications.

1911	Wilhelm Wien	Germany	in Physics for his discoveries regarding the laws governing the radiation of heat
1918	Max Karl Ernst Ludwig Planck	Germany	in Physics in recognition of the services he rendered to the advancement of Physics by his discovery of energy quanta
1921	Albert Einstein	Germany & Switzerland	in Physics for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect
1922	Niels Henrik David Bohr	Denmark	in Physics for his services in the investigation of the structure of atoms and of the radiation emanating from them
1927	Arthur Holly Compton	USA	in Physics for his discovery of the effect named after him
1929	Prince Louis-Victor Pierre Raymond de Broglie	France	in Physics for his discovery of the wave nature of electrons
1932	Werner Karl Heisenberg	Germany	in Physics for the creation of quantum mechanics, the application of which has, inter alia, led to the discovery of the allotropic forms of hydrogen
1933	Erwin Schrödinger	Austria	in Physics for the discovery of new productive forms of atomic theory
	Paul Adrien Maurice Dirac		-do-
1937	Clinton Joseph Davisson	USA	in Physics for their experimental discovery of the diffraction of electrons by crystals
	George Paget Thomson	Great Britain	-do-
1945	Wolfgang Pauli	Austria	in Physics for the discovery of the Exclusion Principle, also called the Pauli Principle
1954	Max Born	Great Britain	in Physics for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wavefunction
1955	Willis Eugene Lamb	USA	in Physics for his discoveries concerning the fine structure of the hydrogen spectrum
	Polykarp Kusch	USA	in Physics for his precision determination of the magnetic moment of the electron
1957	Chen Ning Yang	China	in Physics for their penetrating investigation of the so-called parity laws which has led to important discoveries regarding the elementary particles
	Tsung-Dao Lee	China	-do-
1963	Eugene Paul Wigner	USA	in Physics for his contributions to the theory of the atomic nucleus and the elementary particles, particularly through the discovery and application of fundamental symmetry principles
	Maria Goeppert-Mayer	USA	in Physics for their discoveries concerning nuclear shell structure
	J. Hans D. Jenssen	Germany	-do-
1965	Sin-Itiro Tomonaga	Japan	in Physics for their fundamental work in quantum electrodynamics, with deep-ploughing consequences for the physics of elementary particles
	Julian Schwinger	USA	-do-
	Richard P. Feynman	USA	-do-
1969	Murray Gell-Mann	USA	in Physics for his contributions and discoveries concerning the classification of elementary particles and their interactions
1979	Sheldon Lee Glashow	USA	in Physics for their contributions to the theory of the unified weak and electromagnetic interaction between elementary particles, including, inter alia, the prediction of the weak neutral current
	Abdus Salam	Pakistan	-do-
	Steven Weinberg	USA	-do-
1984	Carlo Rubbia	Italy	in Physics for their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction
	Simon van der Meer	The Netherlands	-do-
1999	Gerardus 't Hooft	The Netherlands	in Physics for elucidating the quantum structure of electroweak interactions in physics
	Martinus J.G. Veltman	The Netherlands	-do-

mechanics. Schrodinger introduced operators associated with each dynamical variable. Then came Heisenberg's uncertainty principle. The Theory was now popularly called Quantum Mechanics. The year 1926 saw the complete solution of the derivation of Planck's law after 26 years by P.A.M. Dirac. The quantum theory was finally established on a firm theoretical basis! Then came the applications of quantum mechanics to understand the basic constituents of matter and attempts to unify the different types of forces (or interactions as scientists call them) we come across in nature, say, strong interaction (between the constituents of the nucleus), weak interaction (in radioactive decay when an electron is emitted or absorbed by the nucleus), the electromagnetic interaction between charged particles and the gravitational interaction. There has been some success – electromagnetic and the weak interactions have been unified into one interaction called electroweak interaction. There have been attempts also to unify the electroweak force with the strong force into a single gauge theory. However, the theory unifying all the four forces we come across in nature still appears to be a distant dream. In any case, one thing is certain – We have to live with quantum theory!

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Quantum theory : Glossary

Important terms used in connection with Quantum Theory are given below. The terms given do not necessarily appear in the present article.

Absolute zero : The temperature of –273.16ºC, or – 459.69ºF, or 0 K, thought to be the temperature at which molecular motion vanishes and a body would have no heat energy.

Absorption coefficient : If a flux through a material decreases with distance x in proportion to e^{-ax}, then a is called the absorption coefficient.

Blackbody : An ideal body which would absorb all incident radiation and reflect none. Also known as hohlrarum; ideal radiator.

Blackbody radiation : The emission of radiant energy which would take place from a blackbody at a fixed temperature; it takes place at a rate expressed by the Stefan-Boltzmann law, with a spectral energy distribution described by Planck's equation.

Bohr-Sommerfeld theory : A modification of the Bohr theory in which elliptical as well as circular orbits are allowed.

Bohr theory : A theory of atomic structure postulating an electron moving in one of certain discrete circular orbits about a nucleus with emission or absorption of electromagnetic radiation necessarily accompanied by transitions of the electron between the allowed orbits.

Carnot cycle : A hypothetical cycle consisting of four reversible processes in succession: an isothermal expansion and heat addition, an isentropic expansion, an isothermal compression and heat rejection process, and an isentropic compression.

Compton effect : The increase in wavelength of electromagnetic radiation in the X-ray and gamma-ray region on being scattered by material objects; the scattering is due to the interaction of the protons with electrons that are effectively free. Also known as Compton-Debye effect.

Conservation of parity : The law that, if the wave function describing the initial state of a system has even (odd) parity, the wave function describing the final state has even (odd) parity; it is violated by the weak interactions. Also known as parity conservation.

D line : The yellow line that is the first line of the major series of the sodium spectrum; the doublet in the Fraunhofer lines whose almost equal components have wavelengths of 5895.93 and 5889.96 angstroms respectively.

Doppler range : A Doppler ranging system that uses phase comparison of three different modulation frequencies on the carrier wave, such as 0.01, 0.1, and 1 megahertz, to obtain missile range data with high accuracy.

Electromagnetic wave : A disturbance which propagates outward from any electric charge which oscillates or is accelerated; far from the charge it consists of vibrating electric and magnetic fields which move at the speed of light and are at right angles to each other and to the direction of motion.

Electron : A stable elementary particle which is the negatively charged constituent of ordinary matter, having a mass of about 9.11 X 10^{-28}g (equivalent to 0.511 MeV), a charge of about –1.602 X 10^{-19} coulomb, and a spin of ½. Also known as negative electron; negatron.

Electron diffraction : The phenomenon associated with the interference processes which occur when electrons are scattered by atoms in crystals to form diffraction patterns.

Equipartition : The condition in a gas where under equal pressure the molecules of the gas maintain the same average distance between each other.

Equipartition law : In a classical ideal gas, the average kinetic energy per molecule associated with any degree of freedom which occurs as a quandratic term in the expression for the mechanical energy, is equal to half of Boltzmann's constant times the absolute temperature.

Erg : A unit of energy or work in the centimeter-gram-second system of units, equal to the work done by a force of magnitude of 1 dyne when the point at which the force is applied is displaced 1 centimeter in the direction of the force. Also known as dyne centimeter (dyne-cm).

Exclusion principle : The principle that no two fermions of the same kind may simultaneously occupy the same quantum state. Also known as Pauli exclusion principle.

Heisenberg picture : A mode of description of a system in which dynamic states are represented by stationary vectors and physical quantities are represented by operators which evolve in the course of time. Also known as Heisenberg representation.

Invariance : The property of a physical quantity or physical law of being unchanged by certain transformations or operations, such as reflection of spatial coordinates, time reversal, charge conjugation, rotations, or Lorentz transformations. Also known as symmetry.

Invariance principle : Any principle which states that a physical quantity or physical law possesses invariance under certain transformations. Also known as symmetry law; symmetry principle. In general relativity, the principle that the laws of motion are the same in all frames of reference, whether accelerated or not.

Node : A point, line, or surface in a standing-wave system where some characteristic of the wave has essentially zero amplitude.

Parity : A physical property of a wave function which specifies its behavior under an inversion, that is, under simultaneous reflection of all three spatial coordinates through the origin; if the wave function is unchanged by inversion, its parity is 1 (or even); if the function is changed only in sign, its parity is -1 (or odd).

Parity conservation : The law that, if the wave function describing the initial state of a system has even (odd) parity, the wave function describing the final state has even (odd) parity; it is violated by the weak interactions. Also known as conservation of parity.

Photoelectric effect : The liberation of electrons by electromagnetic radiation incident on a electrons by electromagnetic radiation incident on a substance; includes photoemission, photoionization, photoconduction, the photovoltaic effect, and the Auger effect (an internal photoelectric process). Also known as photoelectric effect; phtoelectric process.

Planck oscillator : An oscillator which can absorb or emit energy only in amounts which are integral multiples of Planck's constant times the frequency of the oscillator. Also known as radiation oscillator.

Planck radiation formula : A formula for the intensity of radiation emitted by a blackbody within a narrow band of frequencies (or wavelengths), as a function of frequency, and of the body's temperature. Also known as Planck distribution law; Planck's law.

Planck's constant : A fundamental physical constant, the elementary quantum of action; the ratio of the energy of a photon to its frequency, it is equal to 6.62620 ± 0.00005 X 10^{-34} joule-second. Symbolized h.

Planck's law : A fundamental law of quantum theory stating that energy associated with electromagnetic radiation is emitted or absorbed in discrete amounts which are proportional to the frequency of radiation.

Quantum : For certain physical quantities, a unit such that the values of the quantity are restricted to integral multiples of this unit; for example, the quantum of angular momentum is Planck's constant divided by 2π.

Quantum electrodynamics : The quantum theory of electromagnetic radiation, synthesizing the wave and corpuscular pictures, and of the interaction of radiation with electrically charged matter, in particular with atoms and their constituent electrons. Also known as quantum theory of light; quantum theory of radiation.

Quantum field theory : Quantum theory of physical systems possessing an infinite number of degrees of freedom, such as the electromagnetic field, gravitation field, or wave fields in a medium.

Quantum hypothesis : A hypothesis that some physical quantity can assume only a certain discrete set of values; examples are Planck's law, and the condition in the Bohr-Sommerfield theory that the action integral of a system must be an integral multiple of Planck's constant. Also known as quantum postulate.

Quantum mechanics : The modern theory of matter, of electromagnetic radiation, and the interaction between matter and radiation; it differs from classical physics, which it generalizes and supersedes, mainly in the realm of atomic and subatomic phenomena. Also known as quantum theory.

Quantum number : One of the quantities, usually discrete with integer or half-integer values, needed to characterize a quantum state of a physical system.

Quantum statistics : The statistical description of particles or systems of particles whose behaviour must be described by quantum mechanics rather than classical mechanics.

Quantum theory of spectra : The contemporary theory of spectra, based on the idea that an atom, molecule, or nucleus can exist only in certain allowed energy states, that it emits or absorbs energy as it changes from one state to another, and that the frequency of the associated electromagnetic radiation equals the difference in energies of two states divided by Planck's constant.

Quantum-wave equation : A partial differential equation which related the spatial and time dependences of a wave function of a system of one or more atomic or subatomic particles: examples are the Schrödinger equation in nonrelativistic quantum mechanics, and the Klein-Gordon, Dirac, Rarita-Schwinger and Proca equations in relativistic quantum mechanics.

Rayleigh-Jeans law : A law giving the intensity of radiation emitted by a blackbody within a narrow band of wavelengths; it states that this intensity is proportional to the temperature divided by the fourth power of the wavelength; it is a good approximation to the experimentally verified Planck radiation formula only at long wavelengths.

Relativistic mechanics : Any form of mechanics compatible with either the special or the general theory of relativity.

Relativistic quantum theory : The quantum theory of particles which is consistent with the special theory of relativity, and thus can describe particles moving arbitrarily close to the speed of light.

Resonator : A device that exhibits resonance at a particular frequency, such as an acoustic resonator or cavity resonator.

Schrödinger equation : A partial differential equation governing the Schrödinger wave function Ψ (pronounced psi) of a system of one or more nonrelativistic particles.

Schrödinger-Klein-Gordon equation : A wave equation describing a spinless particle which is consistent with the special theory of relativity. Also known as Klein-Gordon equation.

Schrödinger picture : A mode of description of a quantum-mechanical system in which dynamical states are represented by vectors which evolve in the course of time, and physical quantities are represented by stationary operators, in contrast to the Heisenberg picture.

Schödinger's wave mechanics : The version of nonrelativistic quantum mechanics in which a system is characterized by a wave function Ψ (pronounced psi) which is a function of the coordinates of all the particles of the system and time, and obeys a differential equation, the Schrödinger equation; physical quantities are represented by differential operators which may act on the wave function, and expectation values of measurements are equal to integrals involving the corresponding operator and the wave function. Also known as wave mechanics.

Schrödinger wave function : A function of the coordinates of the particles of a system and of time which is a solution of the Schrödinger equation and which determines the average result of every conceivable experiment on the system. Also known as probability amplitude; psi function.

Spectroscope : An optical instrument consisting of a slit, collimator lens, prism or grating, and a telescope or objective lens which produces a spectrum for visual observation.

Spectroscopy : The branch of physics concerned with the production, measurement, and interpretation of electromagnetic spectra arising from either emission or absorption of radiant energy by various substances.

Spectrum : The set of frequencies, wavelengths or related quantities, involved in some process; for example, each element has a characteristic discrete spectrum for emission and absorption of light.

Standing wave : A wave in which the ratio of an instantaneous value at one point to that at any other point does not vary with time. Also known as stationary wave.

Steady state : The condition of α body or system in which the conditions at each point do not change with time, that is after initial transients or fluctuations have disappeared.

Stefan-Boltzmann constant : The energy radiated by a blackbody per unit area per unit time divided by the fourth power of the body's temperature; equal to $(5.6696 + 0.0010) \times 10^{-8}$ (watts) $(\text{meter})^{-2}(\text{degrees Kelvin})^{-4}$.

Stefan-Boltzmann law : The total energy radiated from a blackbody is proportional to the fourth power of the temperature of the body. Also known as fourth-power law; Stefan's law of radiation.

Thermal equilibrium : Property of a system all parts of which have attained a uniform temperature which is the same as that of the system's surroundings.

Thermodynamic equilibrium : Property of a system which is in mechanical, chemical, and thermal equilibrium.

Thermodynamics : The branch of physics which seeks to derive, from a few basic postulates, relationships between properties of matter, especially those which are affected by changes in temperature, and a description of the conversion of energy from one form to another.

Ultraviolet catastrophe : The prediction of the Rayleigh-Jeans law that the energy radiated by a blackbody at extremely short wavelenghts is extremely large, and the total energy radiated is infinite, whereas in reality it must be finite.

Uncertainty principle : The precept that the accurate measurement of an observable quantity necessarily produces uncertainties in one's knowledge of the values of other observables. Also known as Heisenberg uncertainty principle; indeterminancy principle.

Uncertainty relation : The relation whereby, if one simultaneously measures values of two canonically conjugate variables, such as position and momentum, the product of the uncertainties of their measured values cannot be less than approximately Planck's constant divided by 2π. Also knowns as Heisenberg uncertainty relation.

Wave equation : Any of several equations which relate the spatial physical entity which can propagate as a wave, including quantum-wave equation for particles.

Wave mechanics : The version of nonrelativistic quantum mechanics in which a system is characterized by a waveΨ (pronounced psi) function which is a function of the coordinates of all the particles of the system and time, and obeys a differential equation, the Schrödinger equation; physical quantities are represented by differential operators which may act on the wave function, and expectation values of measurements are equal to integrals involving the corresponding operator and the wave function. Also known as Schödinger's wave mechanics .

Wien constant : The product of the temperature and wavelength at which the intensity of radiation from a blackbody reaches its maximum; i is equal to approxumetely 2898 micron-degrees.

Wien's displacement law : A law for blackbody radiation which states that the wavelength at which the maximum amount of radiation occurs times the temperature is a constant equal to approximately 2898 micron-degrees. Also known as displacement law; Wien's radiation law.

Wien's distribution law : A formula for the spectral distribution of radiation from a blackbody, which is a good approximation to the Planck radiation formula at sufficiently low temperatures of wavelengths, for example, in the visible region of the spectrum below 3000K. Also known as Wien's radiation law.

Intellectual Property Rights

(Part-II : Trademarks, Industrial Designs and Copyright)

❑ *Subodh Mahanti*

In the first part of this article we had discussed briefly about the concept of intellectual property and the patent system. Though different types of intellectual property are usually discussed separately, it is always useful to be conversant with all aspects of intellectual property. In this part of the article we will briefly discuss about trademarks, industrial design and copyright.

Trademarks

As stated in the first part of this article, trademarks are visible signs which distinguish the goods and services of an enterprise from those of their competitors. The term "visible sign" covers a whole lot of things. It includes any of the following or combinations thereof :

- Arbitrary or fanciful designations
- Names
- Existing and invented words
- Slogans
- Devices
- Numbers and their combinations
- Letters
- Pictures or symbols
- Labels
- Combinations or arrangements of colours
- Shapes of the containers or of the goods themselves

Besides dealing with goods, enterprises also render services like travel, advertising, transport, insurance, treatment of materials etc. To identify such services "service marks" are used. There is hardly any difference between a trademark and a service mark except the fact that a trademark is associated with goods and a service mark with services. Normally, the word "trademark" is used in a broad sense which includes trademarks that distinguish goods, service marks, collective marks and certification marks.

Trademarks typically identify individual enterprises as the origin of marked goods or services. In most countries the trademark laws have provision for the registration and use of collective marks, visible signs that serve to distinguish the origin or any other common characteristic of goods or services of different enterprises. Usually the owner of a collective trademark is a co-operative, an association of enterprises or an institution of public character. Collective marks are used to indicate membership and to inform public about certain features of the product for which the collective mark is used. Certification marks are used by various entities to certify the characteristics of goods or services. The main difference between collective marks and certification marks is that the former may be used by particular type of enterprises, for example members of a co-operative, the owner of the collective marks, while the latter may be used by anybody who complies with the defined standard. An entity can apply for certification mark only if it is "competent to certify" the products concerned. The definition of 'certification mark' may vary from country to country.

A trademark need not be supported by high tech products. It may be applied even to the most ordinary product or service. Trademarks can also be used for agricultural products.

The practice of using trademark is not a new one. For centuries, craftsmen and manufacturers in different parts of the world have marked their products with sign of one kind or another to distinguish them from those of their competitors. As long as 3,000 years ago, Indian craftsmen used to engrave their signatures on their artistic creations before sending them abroad.

A trademark has several functions. Some of the important functions are given below:

- A trademark usually represents certain standard of quality and uniformity to consumers. Thus a trademark guides a consumer in his/her decision to buy a product among different brands available in the market.
- With the help of a mark, an enterprise can draw the attention of probable consumers to the availability of the goods bearing that mark and subsequently hold their attention once they are acquainted with the goods. It may be noted that while trademark is perceived as a means to distinguish goods (or services) of one enterprise from another, a consumer may not necessarily know the name of the enterprise that manufactures or markets a product with a particular trademark.
- A trademark enables the manufacturer to identify goods manufactured by him/her even when they are not in his/her possession, but have gone to different selling points.
- Once a mark acquires certain reputation, it enables its owner to penetrate new markets.
- It enables the authorities responsible for controlling the quality of the goods sold under a particular trademark to do their job.
- An effective trademark system helps to protect the consumers against various forms of unfair trading practices like the use of misleading marks or of confusingly similar marks.
- The national authorities entrusted with the responsibilities for verifying the quality and other characteristics of goods and services find marks very useful.
- The registration of marks constitutes a useful source of statistical and economic information for the national authorities.

Three main aspects of trademark activities are : selection of trademarks; obtaining protection for trademarks and subsequent maintenance and monitoring the trademark activities of competitors.

Great care is required while choosing a particular sign for adoption as a trademark. Often a trademark conveys the first impression that of a product or service to a consumer. Moreover, a trademark should be chosen in such a way that it should not cause any registration or infringement problem. To avoid these problems an enterprise comes up with a short list of possible trademarks to be applied to a particular product or range of products. This process is known as 'preliminary clearance'. Any sign cannot be registered as trademark. There are certain legal requirements to be met for getting a sign registered as trademark. Any of the following criteria can disqualify a sign from becoming a valid trademark :

- A sign without any distinctive character but simply consisting of shape or forms imposed by the inherent nature of the good or service or by its industrial function.
- A sign consisting exclusively of an indication which may serve to designate the kind, quality etc., of the goods or services.
- A sign which, in the course of trade, has become customary designation of the goods or services concerned.
- A sign which is likely to deceive the public as to the nature,

geographical origin, characteristics or suitability of the goods.

- A sign which is in conflict with the existing trademarks. A sign should have no resemblance with an existing trademark for the same or similar goods or services.
- A sign representing immoral, deceptive or scandalous matter.
- A sign representing any national symbols.
- A sign which may tend to indicate a connection with, bring into contempt or disrepute, persons (living or dead), institutions or beliefs.

So after choosing a sign for adoption as trademark, a search must be undertaken to find whether any similar trademark has already been registered.

For getting a trademark legally protected a trademark has to be registered in the trademark register of the industrial property office of the country in which protection is sought. International registration with the International Bureau of WIPO can also be obtained if the enterprise has its headquarters in a country which is party to the Madrid Agreement Concerning the International Registration of Marks. The application for registration must contain a replica of the trademark for which protection is sought. Once the trademark is registered its owner can prevent anyone from applying the mark or one resembling it to goods or services of the same description as that or those for which the mark is registered. The owner can prevent anyone from using it even when it is applied to goods or services of a different description if it creates confusion or amount to taking advantage of the reputation of the registered mark.

The registration of the trademark is always granted only for a limited period of time. However, unlike patent a trademark once registered can be renewed in perpetuity. So a trademark may remain protected indefinitely. The renewal of a trademark is not automatically done. The owner will require to request for the renewal and pay a renewal fee.

In some countries a trademark can be protected only if it is in use; that is, goods or services bearing the mark are available in the market for sale. In such countries, the time limit within which use must begin after registration is laid down. If the owner of the trademark fails to use it within this timeframe without any legitimate ground for not using it, the trademark is struck off from the register.

The owner of a trademark must ensure that it does not become a generic or a common designation. To achieve this, one may adopt the following :

- The protected trademark should be used in such a way which sets them apart from other words.
- Wherever possible the trademark must accompany the registration symbol R or the symbol TM for non-registered trademarks.
- A trademark should be made to stand out by some other means may be underlined or enclosed in quotation mark.
- A trademark should also be used as an adjective followed by the generic name of the product or service which it identifies.
- The spelling of a trademark should never be changed or a new word made from it.
- If a trademark is in the form of symbol or logo it should be ensured that correct proportions are maintained in the trademark's shape. Where colours are specified in trademark's registration same colours should always be used.

It should be noted that a trademark need not be registered before they are used. The registration of a trademark ensures its legal protection. In fact some borderline trademarks can become registrable only after many years of their use when it can be proved that they have become distinctive in the trade.

To ensure that trademarks are not being infringed, an enterprise should constantly monitor the trademark activities of their competitors. The monitoring activity may be done inhouse or by a professional watching service. The monitoring activity may be quite cost intensive if a trademark is registered in several countries.

The International Classification of Goods and Services for the Purposes of the Registration of Marks established under the Nice Agreement is used by more than 110 countries.

Industrial Designs

Industrial design refers to the creative activity of achieving a formal or ornamental appearance for items produced industrially. The conception or idea that constitutes the design may be something which can be expressed either two-dimensionally or three-dimensionally. The term industrial design also refers to the fact that the items must be reproducible by industrial means or the design is capable of being used in industry to produce the articles embodying the design on a large-scale. In case it is not industrially reproducible then the creation is in the category of a work of art that is protected by copyright law and not by industrial property law. The design should be such that it satisfies both the need for the item to appeal visually to potential consumers and the need for the item to perform efficiently its intended function.

For protecting an industrial design it must be new and/or original. Industrial designs are usually protected against unauthorised copying or imitation. A design that is applied to or embodied in an article must have an appearance which is capable of visual judgement. An industrial design protection is concerned solely with appearance aspect of articles and not with their functions. The usual criteria that are considered in deciding whether a design is registrable or not are: shape, configuration, pattern or ornament.

The meaning of the term 'shape' is obvious. The term 'configuration' refers to the arrangement of the component parts of an article. The terms "pattern" and "ornament" are not clearly distinguishable from each other. The pattern of an article may refer to its surface treatment whereas ornamentation of an article may refer to the fact that there are bits added on to its basic shape.

The usual protection period for an industrial design may last for five, ten or fifteen years. The document certifying the protection of an industrial design may be called registration certificate or a patent. When it is called patent, it should always indicate that it is a patent for an industrial design so as to distinguish it from a patent for invention. Many countries grant protection under their copyright laws without registration, to an industrial design that can be considered artistic works applied to industry. Like a patent, an industrial design cannot be disclosed to the general public before an application is filed for its registration.

An application for registering an industrial design usually contains the following :

1. A request for registration.
2. The name and address of the applicant.
3. A specimen or photographic or graphic representation of the article embodying the design.
4. An indication of the kind of product to which the design is to be applied.
5. The registration fee as laid down by the industrial property law of the country in which the application is filed.

Once on being examined if it is found that the design is registrable its details are recorded in a national design register. The registration once effected stays in force for a certain period of time usually five years and which may be renewed. However, like a patent but unlike a trademark, an industrial design cannot be renewed for indefinite period. The usual maximum period goes from 10 to 15 years.

Like a patent, the owner of an industrial design can prevent anyone else from infringing the registered designs.

In case the enterprise is in a country party to the Hague Agreement Concerning the International Deposit of Industrial Design, it can deposit its industrial designs internationally that is, with the International Bureau of WIPO.

The difference between protection by the copyright law and protection by the industrial design law are as follows:

Protection by Industrial Design	**Protection by Copyright Law**
A design must be applied to utilitarian articles in order to be protected.	The protection is purely concerned with aesthetic creations.
The protection is lost unless industrial design is registered by the applicant before publication or public use.	The protection subsists without formalities. Registration is not necessary.
Industrial design protection endures generally for a short period (10 to 25 years)	Copyright lasts in most countries for the life of the author and fifty years after his/her death.

Copyright

Copyright protection is concerned with particular forms of creativity related to mass communication. It deals with virtually all forms and methods of public communication — printed publication, sound and television broadcasting, films for public exhibition in cinemas etc. The objective of copyright law is to stimulate and foster the individual creativity and to make the products of that creativity available by disseminating it on the widest extent possible. The prerogatives that constitute copyright are not only enjoyed by the author throughout his/her life, but also remain protected for a certain period even after the death of the author. The period of protection that is given after the death of the author is generally fifty years. In India this has been made 60 years. Copyright law has specified sanctions to deal with unauthorised use (infringement) of a work protected by copyright. The sanctions may be civil or criminal depending on the nature of the infringement. However, once the copyright protection expires, the work falls into the public domain and then it can be used by anyone without authorisation.

Copyright law protects only the form of expression of ideas; not the ideas themselves. Once an idea of an invention (for example an idea on how to make an efficient car engine) is expressed in tangible form, for example in the form of written article, the copyright protection exists for the article. The author can prevent a third party from reproducing the article. But then, one can make use of the invention. To protect the use of the invention one must go for patent protection.

A work is entitled for copyright protection even if it is considered bad and even if it fails to save the purpose for which it was intended. The copyright protection is not concerned with the use to which a work may be put.

To be protected by copyright law the author's work must be original, it must originate from the author. However, to qualify for protection, the work is not required to pass a test of imaginativeness, of inventiveness. The protection is independent of the quality or the value attaching to the work.

The practical value of copyright law depends on the extent to which they are effectively implemented. It serves as an incentive to authors and their assignees to create and disseminate knowledge.

The copyright laws of almost all countries provide for the protection of the following types of works:

- i. Literary works: Novels, short stories, poems, dramatic works and any other writing irrespective of their content, length, purpose, form and whether published and not published.
- ii. Musical works : Whether serious or light, songs, choruses, operas, musicals and operettas.
- iii. Artistic works : Whether two-dimensional like drawings, paintings, etchings, lithographs etc. or three-dimensional (sculptures and architectural works).
- iv. Maps and technical drawings.
- v. Photographic works : Whether may be the subject matter and the purpose for which made.
- vi. Motion pictures or cinematographic works, whether silent or with a sound track and irrespective of their purpose, length, method employed or technical process used.
- vii. Computer programmes.

In addition to above, the copyright laws of many countries protect also "works of applied art" (for example artistic jewellery, lamps, wallpaper, furniture etc.), choreographic works, phonograph records, tapes, and broadcasts.

The rights conferred by copyright law on the owner of a work protected by copyright are often described as exclusive rights. The owner may use the work as he/she wishes (of course, he has to regard the legally recognised rights and interests of others). The owner may exclude others from using it without his/her authorisation.

The different rights conferred by copyright law are :

i. Reproduction rights : The owner of copyright may exclude others from making copies of his/her protected work. The expression "copyright" refers to the main act, the act of making of copies of artistic work.

ii. Performing rights : The act of public performance requires authorization from the owner of copyright. This is important because a work protected by copyright may be communicated to a large number of people without being copied or reproduced.

iii. Recording Rights : One requires authorisation from the copyright owner for making sound recording of work protected by copyright. Just like, by written words a work protected by copyright can be communicated by sound recording and copies of sound recordings can be made as easily as copies of writings.

iv. Motion picture rights : The act of making motion picture or visual recording, presenting to viewers as continuous sequence of images is controlled by copyright law. In the technical language of copyright laws motion picture is often called "cinematographic work". In some countries instead of motion picture the word `film' is used.

v. Broadcasting rights : The acts of broadcasting works and of communicating works to the public by means of wires or cable require the authorisation of the copyright owner

vi. Translation and adoption rights : The acts of translating or of adapting a work protected by copyright require the authorisation of the copyright owner.

vii. Moral rights : The countries party to the Berne Convention are required to grant to authors :

a) The right to claim authorship of the work

b) The right to object any distortion or other modification of the work which would be prejudicial to the author's honour or reputation.

It should be emphasized that copyright comes into force without registration or other formalities. So the question of applying for protection does not always arise. However, registration may be required for other purposes like enforcing the right. It is not always easy to prove that a third party has copied a particular work. Copying is always done in private.

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