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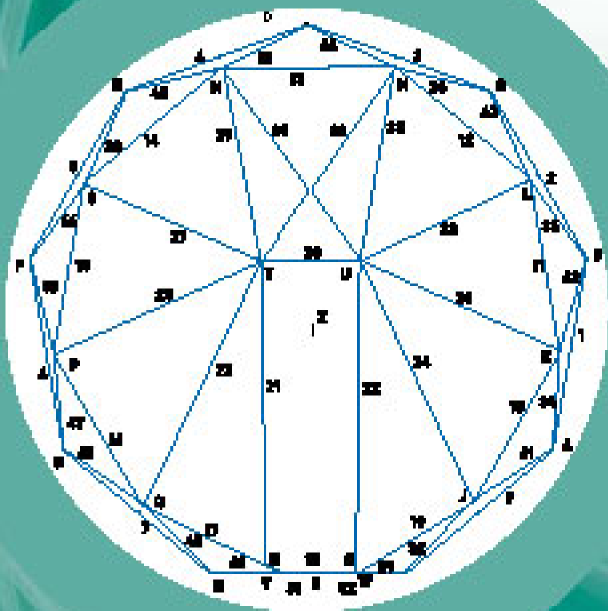

The structure of the Nanogonal Rotating Observation Hut is capable of being used as a portable observatory, when constructed by light-weight bars and tarpaulin cover

To Our Contributors

School Science is a journal published quarterly by the National Council of Educational Research and Training, New Delhi. It aims at bringing within easy reach of teachers and students the recent developments in science and mathematics and their teaching, and serves as a useful forum for the exchange of readers' views and experiences in science and mathematics education and science projects.

Articles suitable to the objectives mentioned above are invited for publication. An article sent for publication should normally not exceed ten typed pages and it should be exclusive to this journal. A hard copy of the article including illustrations, if any, along with a soft copy should be submitted in CD. Photographs (if not digital) should be at least of postcard size on glossy paper and should be properly packed to avoid damage in transit. The publisher will not take any responsibility or liability for copyright infringement. The contributors, therefore, should provide copyright permission, wherever applicable and submit the same along with the article.

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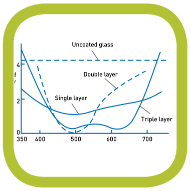
Contents


Uncoated glass
Double layer
Single layer
Triple layer
4
2
0
350
400
500
600
700

EDITORIAL

Physics is a general analysis of nature, conducted in order to understand how the universe behaves, and also it is one of the oldest academic disciplines because it includes astronomy. In the present issue, fifth and last in the series on the completion of 50 years, we have included articles from various disciplines of physics and astronomy.

In "Mini Workshop on a Bicycle", the author demonstrates that the power, generated at the bicycle pedals, can solve the problems of the day-to-day household repairs, grinding, turning, coil winding, drilling, etc. And the paper "Bullock-cart: A Laboratory for Science Teaching" describes some basic principles of work, force and motions with the help of bullock-cart as a teaching aid.

"Open-ended Experiments in Developing Cognitive Abilities" is an interesting article in which the author discusses open-ended approach for doing physics experiments and examining its effectiveness by field tests.

In "Teaching the Effects of Force at Grade Level VI: Textual Activities versus Hands-on Activities", the author discusses about the effects of force and says that it is related to daily life situations, and that students can enhance their observation power when they identify the situations in the school environment wherein the effects of force are visualised.

In the article, "Education in Physics for Rural Children", the author concludes that physics should largely be experimental and the curriculum must be smart and flexible, and the methods and values of physics must form a part of the classroom lessons, thus it requires support to the rural teachers.

In "Gravity in Action", the author examines the phenomena and laws like Kepler's law and law of gravitation which are direct consequences of the gravity.

In the article, "Nuclear Technology and Public Health", the author discusses about the advantages of nuclear technology, nuclear accident and nuclear waste disposal with its effect on environment and health. The author also observes that the successful introduction of this technology requires interdisciplinary collaboration among the relevant scientists, various government regulatory and financial agencies and industries.

In the article, "How Big is the Moon and How Far is the Sky?", the author in an interesting way estimates the size of heavenly bodies when they are near the horizon and when they are high up in the sky. It also proves that the moon, sun, and stars appear several times more distant when at the horizon than at the zenith.

In the article, "Astronomy in Science and in

Human Culture", a Jawaharlal Nehru Memorial Lecture 1969, the author dissertates the contribution of scientists like, Hubble, Kepler, Newton, Galileo, etc., with their respective theories and laws in understanding astronomy. Besides, the author discusses about the Indian astronomers who went deep into the matter and tried to theorise all the natural phenomena during their three definite phases of astronomy.

In the article, "What is the Universe Like?", the author considers the universe from the eyes of an astronomer or an astrophysicist and describes the astronomer's view from the beginning of the telescope to planet then to galaxies to black hole, the location of earth and human species, etc.

In the article, "India's Contribution to Astronomy: Religious and Historical Background", the author describes that the Indian astronomers did lay the foundation, the generalisation, which during the sixteenth and seventeenth centuries became the main feature of the rapid development of astronomy in the West.

In "A Portable Nanogonal Rotating Hut for Observational Astronomy Activities in School and Colleges", the researcher describes that for any systematic study of celestial bodies over several days or weeks in an educational institution, it would be better to install telescope permanently at the terrace or in an open field, at least for the duration of particular project.

In the article, "An Urgent Need for Inclusion of GIS in the Curriculum of Geography and Computer Science", the author explains about the geographical information system technologies and their application, relevance and importance in the courses of both geography and computer science.

In the article, "First Indian at the South Pole", the author shares various moment of the journey to Antarctica, i.e., from getting adaptability certificate to the climax of Antarctic expedition, and briefly describes their observations and innumerable difficulties faced during winter.

In the article, "Why do Camera Lenses Appear Coloured?", the researcher discusses about 'ripe plum color bloom' and 'bloomed lens' and thus that camera lens provided with such anti-reflection or non-reflective coating are more popularly described as 'coated lens' or 'bloomed lens'

We sincerely hope that our readers would find the issue interesting and educative. Your valuable suggestions, observations and comments are always a source of inspiration which guide us to bring further improvement in the quality of the journal.

MINI WORKSHOP ON A BICYCLE

P.K. Bhattacharyya

Workshop Department
National Council of Educational Research and Training New Delhi

Some basic hand-tools and simple machine tools are required for developing prototypes, maintaining equipment, making models for hobby centres and even for day-to-day household repairs. Those who like to enjoy the charm of working with their own hands often face the problem of grinding, turning, facing, coil winding, drilling, etc. These are very common operations required for a small job. School children generally work on light sheet metals and wood (which can be easily fabricated) while making their own models. They also require similar operations to be done on those. Those who are to set up models on electricity (low voltage) will not like to work with torch cells if other source of electricity is available. This is due to various difficulties with the torch cells. Schools and hobby centres having electricity supply can use motorised units for fabrication works. For a typical rural situations, we then have to think of some mechanically driven implements. For designing school science equipment, we have encouraged the use of common indigenous materials which are available everywhere. The power, generated at the bicycle pedals, can solve some of those problems nicely. Bicycle is available everywhere. Only some attachments are to be fitted in it to serve the purpose.

Power Developed at the Bicycle Pedal

The average effort that is generally given at the pedal by the cyclist is 15 kg. At moderately high speed, the pedal is rotated at 66 R.P.M. Taking the pedal radius [illegible]0 mm-

HP generated = $\frac{2\pi NT}{75 \times 60}$ where N = R.P.M

T = Torque in kgm

$$= \frac{2\pi \times 66 \times (15 \times .18)}{75 \times 60} \cong 0.24 \text{ (Nearly)}$$

Attachment to utilise the Power at the Pedal in Cutting, Grinding, etc.

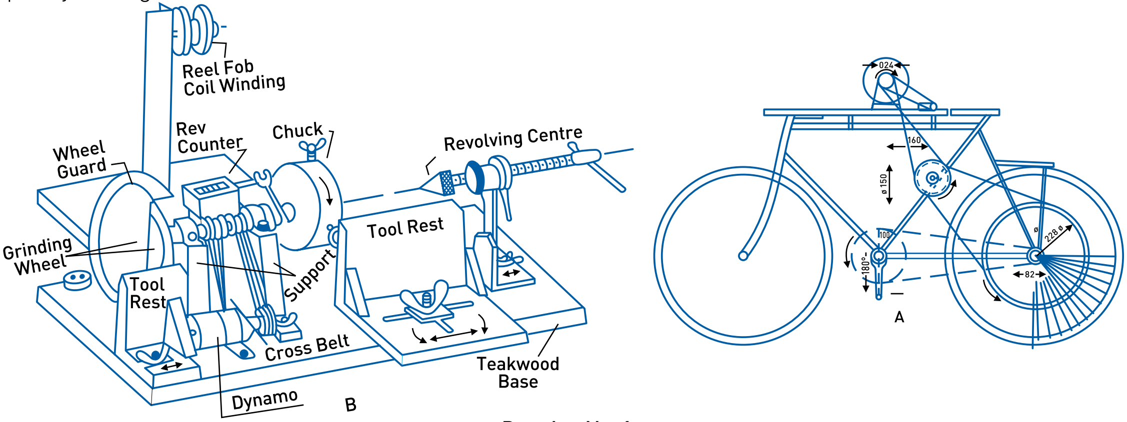
Drawing No. 1 shows the power transmission arrangement. Attempts in arranging the pulleys have been made in such a manner that a very high R.P.M. may be obtained at the chuck. Thus, if the pedal rotates at the 66 R.P.M., the chuck will rotate at –

$$66 \times \frac{100}{41} \times \frac{228}{75} \times \frac{75}{12} = 3058 \text{ R.P.M.}$$

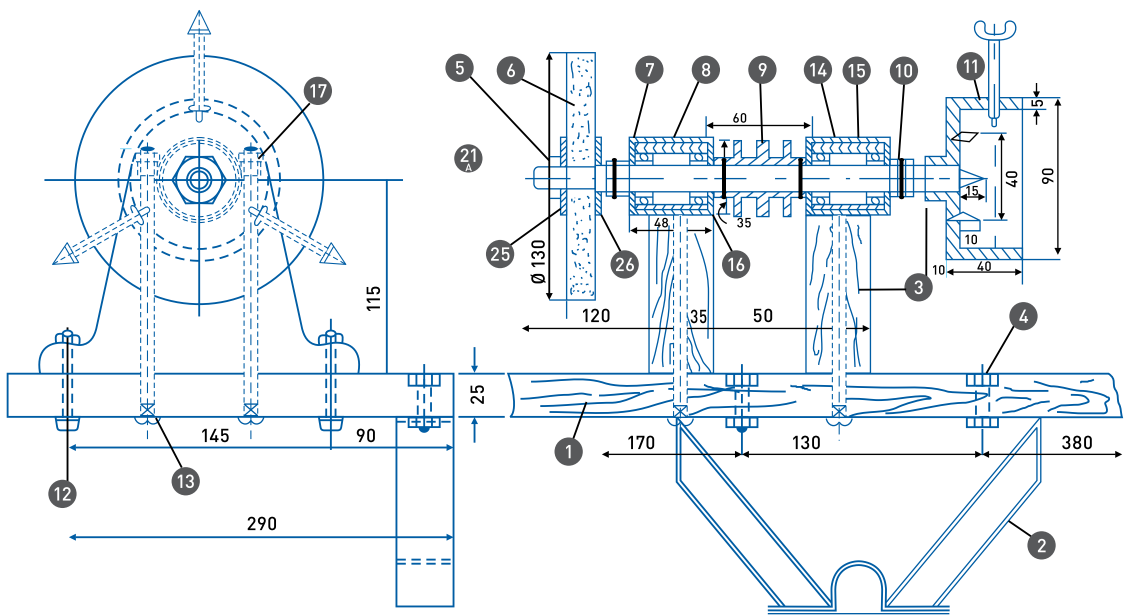
Considering a slip of 5% on each belt the R.P.M. at the chuck will be –2700 R.P.M.

Drawing No. 1 shows that a sheet metal rim of 228 mm radius is fitted to the rear wheel. This rim is fixed in position with the help of thin wires wrapped around the spokes. The compound pulley at the frame is rotated by the rim through the open belt and the 24 mm diameter pulley on the main spindle is rotated by the compound pulley through cross belt.

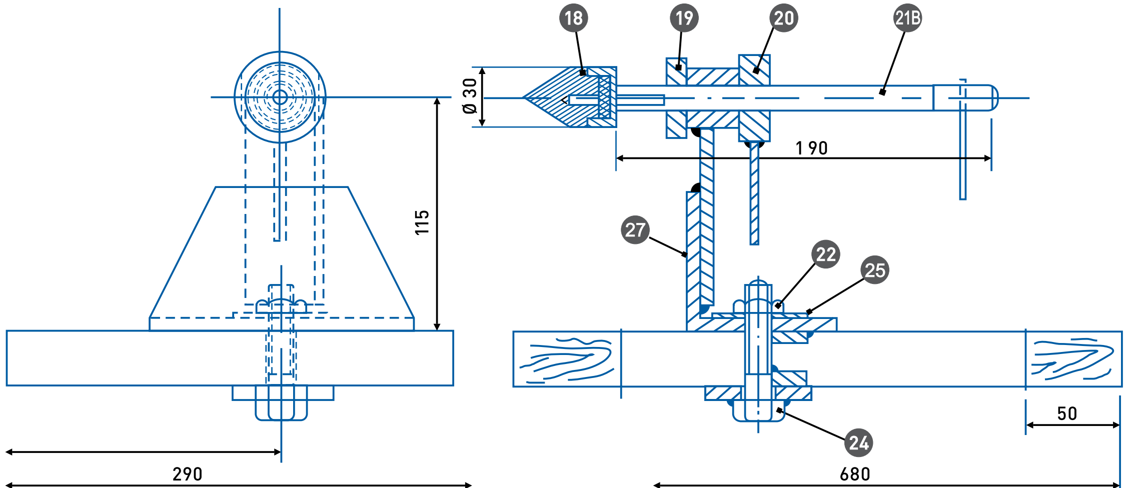
Two supports are to be fitted on the horizontal pipe of the bicycle frame. On these supports, a teakwood base with the chuck-tail stock assembly will be mounted. Drawing No. 1 shows (from the left): plug point, the grinding wheel



Drawing No. 1



Drawing No. 2



Drawing No. 3

17.	Nut	M.S.	2	Plated
16.	Ball Bearing	M.S.	2	No. 6002 15
15.	Bush	M.S.	2	
14.	Spacer	M.S.	2	
13.	Stud M6×150	M.S.	4	Plated
12.	Nut Bolt M6×50	M.S.	4	
11.	Chuck	C.I.	1	
10.	Bush	M.S.	2	
9.	Pulley	M.S.	1	
8.	Bracket	M.S.	2	Black Paint
7.	Cover	M.S.	2	Plated
6.	Grinding Wheel		1	150 ø /
120×20				
5.	Nut M12	M.S.	1	Plated
4.	Nut & Bolt M6×30	M.S.	4	Plated
3.	Support Block	Wood	2	Green Paint
2.	Bracket	M.S.	2	Black Paint
1.	Base Wood	Teak	1	Green Paint

34	Bicycle Dynamo		1	
33	Revolution Counter	6 Digit	1	
32A&B	Tool Rest	Wood	2	Painted
31	Cycle			22/24
30	Rim	M.S.	1	Plated
29	Pulley	Wood	1	Green Paint
28	Bracket	M.S.	1	Black Paint
27	Bracket	M.S.	1	
26	Washer	M.S.	1	
25	Washer	M.S.	1	
24	Bolt with Washer	M.S.	1	Plated
23	Washer	M.S.	1	Plated
22	Nut M12	M.S.	1	
21 B	Tail Stock Screw	M.S.	1	Plated
21 A	Shaft	M.S.	1	
20	Nut with Handle	M.S.	1	Plated
19	Nut	M.S.	1	Plated
18	Revolving Centre	M.S.	1	with 8 mm Ball Bearing
Item	Description	MAT	No. off	Remarks

Drawing No. 4: Bill of Materials

with guard and tool rest, wooden supports for the spindle, revolution counter for coil-winding, cross belt connection to the compound pulley, open belt connection to the dynamo, the chuck, the tool rest for turning, facing, etc. and the tail stuck with the revolving centre. The two tool rests can be adjusted as shown and the tail-stock can be moved back and forth for long and short jobs. The details of the chuck, the tail stock, the bill of materials can be seen in Drawing Nos. 2, 3, 4 respectively.

Operation

The arrangement is suitable for wood-work. On one side, the log is to be held in the chuck either on the centre and two pins (Drawing No.2) or by screwing in the three screws depending on the size of the log; on the other side, the revolving centre will be pressed on to the log by means of screw and nut (Drawing No.3). The cycle is to be supported on its stand, so that the rear wheel is lifted from the ground. The tool rest is to be adjusted to the desired position and fixed in this position by the fly-nut. First few pedals will overcome the inertia of the whole system and after 15-20 pedallings, the fly-wheel action of the chuck will be observed. The operator will hold the tool with both hands, rest it on the tool-rest and advance it towards the job held between the centres. The grinding operation is comparatively easier. While winding coils, the spindle is to be rotated at a lower speed and the revolution will be read from the revolution counter. For all these operations, the operator will sit on the carrier and pedal with his legs.

The dynamo will produce electricity. While peddling, if a bulb is connected to the plug-point on the base, it will glow brighter with higher speed of peddling.

Salient Features

(a) All the attachments are detatchable.

(b) All the parts are easily repairable/replaceable.

(c) The extra pulley on the main spindle may be utilised for transmitting this motion to any desired equipment set-up.

Understanding Mechanics

The power transmission can be a lesson for the students. This can also be accompanied by calculations of mechanical advantage and velocity ratio, etc. This simple and indigenous arrangement may motivate many to think on similar lines and in addition help develop basic skills in handling machine tools.

BULLOCK-CART: A LABORATORY FOR SCIENCE TEACHING

M.V. Lambhate
U.S. Choudhari
Department of Education
University of Indore

Science has been made a basic component of our school education, but in the absence of its relation to the life and environment of the learner it has degenerated into a dogma. It is emphasised in the books that "Science is Doing" but it is actually taught in the classroom in the style of history and civics. The teaching of science in school is largely bookish and theoretical. Teachers tell the facts and students note them down, or students read out some passages from the book in the presence of the teacher. In the rural areas the condition is still worse as far as the facilities for teaching science are concerned.

But a resourceful and imaginative teacher can still do better if he or she carefully observes and makes use of a variety of materials and apparatus available in the rural environment. To me, a bullock-cart can be a very good laboratory for explaining and demonstrating a number of principles involved in the teaching of physics.

In the rural areas it is a challenging job for a teacher to introduce scientific concepts to the learner without audio-visual aids or a laboratory. The school conditions in villages are not very encouraging for science teaching. Still, a skillful teacher, conscious of the environment, can clarify scientific concepts and principles to the children by using the objects around.

Under such unfavourable circumstances, a teacher can select the objects, tools and many other things which are easily available in the adjoining areas for teaching science.

In the villages there are many things which can be used as focal points for teaching scientific principles. The bullock-cart is the commonest among them. In it, a number of scientific concepts and principles are hidden. If these are exposed and explained properly to the students, their learning will be facilitated. At least the following concepts can be taught with ease by using the bullock-cart.

(i) Force

Force is defined as that which changes or tends to change the position of rest or of uniform motion of a body along a straight line, i.e., it produces or destroys a motion. This can be introduced to the class easily. The bullocks apply muscular force to the cart and the cart starts moving in their direction. If during the motion the bullocks stop, the cart will also stop, i.e., the

The authors thank Dr B.K. Pasi, Head of the Department of Education, University of Indore, for enriching an earlier draft of this paper.

bulls apply a force
which produces or destroys the motion of the cart.

(ii) Principle of Work

The work done by a force is defined as the displacement of a body in the direction of a force when the force is applied to it. Here the bullocks apply a force in a forward direction, and the effect
is a displacement of the cart in the forward direction. The force (pull of the bullocks) acts on a body (cart) and the cart is displaced in its (force) direction.

This is an example of work done by a force on a body.

Work done = Force $\times$ Distance

(iii) Wheel Axle

Surface dragging is very difficult and it requires great force. To economise the use of force, a wheel is made to rotate around a fixed axle. This means that even a small force can rotate a wheel more easily than the force required to drag the same body. In a rolling cart friction is much smaller than a sliding one. Rotatory motion helps the cart move very smoothly.

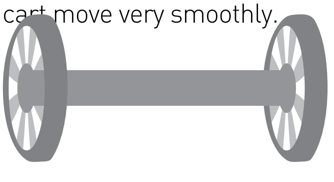


Fig. 1 Wheel axle

(iv) Friction

Sometimes the wheel of the cart does not rotate very smoothly round the axle. Then the cart driver drops some oil in between the wheel and axle. This lubrication helps the wheel move smoothly. The heaviness of the movement is due to the opposing force in between the surfaces of the inner portion of the wheel and the axle. Actually, these surfaces become rough and oppose the motion over each other. This opposing force between the two surfaces is known as frictional force and the phenomenon is called friction.

(v) Type of Motions

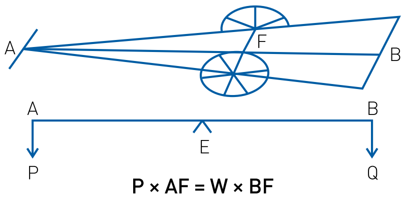
There are two types of motion and these can be demonstrated very effectively with the help of the bullock-cart. The bullock-cart is a unique example in which we can find both the motions, i.e., rotatory as well as translatory.

When the bullocks pull the cart, the wheels start rotating and the body of the cart moves in a straight line, i.e., it possesses a translatory motion. A relation between the rotatory motion and translatory motion can be established. The cart will move in a straight line equal to the perimeter of the wheel.

(vi) Lever

If we observe a bullock-cart, it can be seen that the axle of the wheel serves as a fulcrum and the distances of rods on either side of the fulcrum are unequal. This type of arrangement represents the first principle of lever. The rod towards the bullocks is longer than the body of the cart on the other side of the axle. The distance being longer towards the bullocks, even lean and thin bullocks can pull a heavy load.

LEVER



P × AF = W × BF

Fig. 2

(vii) Parallel Forces

Forces, the lines of action of which are parallel, are called parallel forces. If two equal parallel forces are applied to a rigid body in the same direction, the resultant of them will be a sum of the magnitudes of the two in the same direction.

Parallel Force

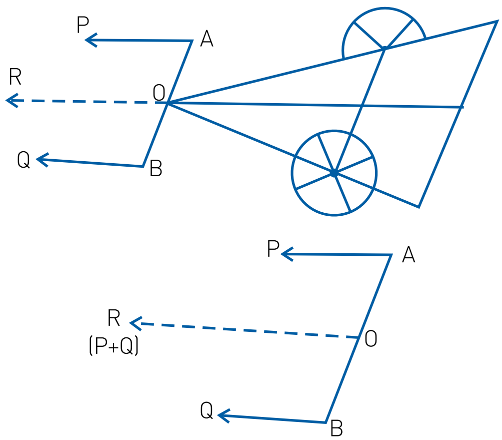


Fig. 3

In the bullock-cart, two bullocks, nearly of the same strength, are used to pull the cart in the forward direction. The cart is pulled forward with a force equal to the sum of the forces applied by the two bullocks and is applied to the centre of the body of the cart.

(viii) Resoluton of Forces

The bullocks pull the cart in the forward direction; on resolution, the force at right angles, as shown in Fig. 4, one component has upward direction while the other has forward direction. The upward component nullifies the weight of the body and the force of the friction. The effect is that the cart becomes somewhat lighter and can be pulled easily by the bulls. So pulling is easier than pushing the cart.

Resolution of Forces

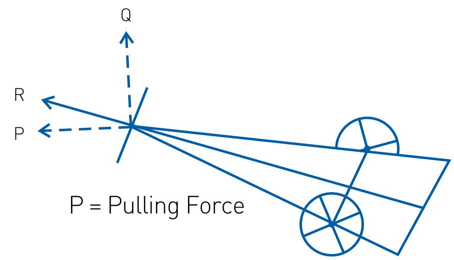


Fig. 4

Idea of Centre of Gravity

The bullocks pull the cart through a wooden rod which is connected at the centre of the body as shown in Fig.5 at C. Instead of pulling the whole body from all sides it is easier to pull it through a point in the middle of the body. It is supposed that the mass of the cart is functionally located at this point. In Fig. 5, O is such a point. The point is called C.G. of the cart. By applying a force, the line of action of force passes through O (C.G. of the cart) and the whole cart is pulled.

Centre of Gravity

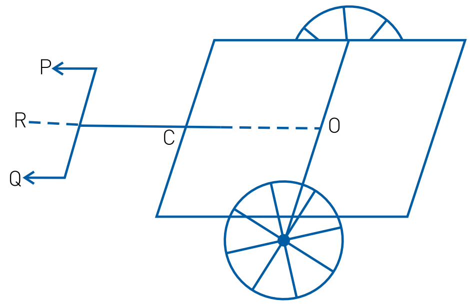


Fig. 5

Heating Effect

The heating effect on a body can be shown very easily. A cart-wheel has two parts, the iron tyre and the wooden structure. In practice the diameter of the iron rim is some what less than that of the wooden wheel. On heating, the iron tyre expands and the diameter becomes equal to the diameter of the wooden wheel. Now the iron tyre is fixed on the wooden wheel and cooled. On cooling it contracts and grips the wooden wheel well. Thus heating and cooling effects can be demonstrated without any apparatus.

Here an attempt has been made to illustrate a few concepts and principles of physics with the help of the bullock-cart. The conscientious teacher can further explore his environment to use other objects to teach science concepts.

OPEN-ENDED EXPERIMENTS IN DEVELOPING COGNITIVE ABILITIES

S.G. Gangoli
C. Gurumurthy
Regional College of Education
National Council of Educational Research and Training
Mysore

Laboratory activities play a very important role in Physics and hence efforts are continuously made all over the world to improve laboratory instruction. This paper discusses open-ended approach for doing Physics experiments and examining its effectiveness by field tests.

Laboratory activities play a very important role in Physics instruction because they are aimed to develop:

(i) Scientific knowledge, cosnceptual understanding and ability to apply scientific knowledge to life-situations.

(ii) Skills—organisational, manipulative, communicative and constructional.

(iii) Creative ability, intellectual ability, problem solving techniques, processes of Science, curiosity to know 'why', 'what' and 'how' of thing, belief in cause and effect relationships, impartial judgements, etc.

Efforts are continuously made all over the world to improve laboratory instruction. Many are of the opinion that approaches emphasising some amount of divergent thinking and openness in the activities are more advantageous than the traditional approach to promote the above objectives. Accordingly, we have been working on open-ended approach for doing Physics experiments and examining its effectiveness by field tests.

The open-ended approach of performing experiments has been defined differently by different authors. Horowitz[1] defines openness as style of teaching involving flexibility of space, student's choice of activity, richness of learning materials involving more individuals or small group activity than large group interaction. This description compares well with our definition of open-ended experiments[2]. But pure open-ended experiments may not be feasible in a real classroom situation in a developing country like India. Hence we have suggested a guided discovery approach for doing practicals[3]. The general format for doing experiments by this approach is as follows:

(i) Area

(ii) Topic

(iii) Pre-requisite knowledge

(iv) Apparatus and materials

(v) Outlines of the possible activities

(vi) Evaluatory questions

(vii) Suggestions by the student for further activities

Some guidance is provided to them by suggesting outlines of the possible activities and by listing suitable evaluatory questions. In a previous project, we have developed a series of open-ended experiments according to the above format.[4]

In this project[5] we have made a comparative study of the effectiveness of open-ended approach versus traditional approach for doing Physics practicals at the P.U.C. (Higher Secondary) level. Five guided open-ended experiments were tried out in Saradavilas College and Marimallappa's Junior College of Mysore city. The sample size was limited to 92 students comprising of 66 boys and 26 girls.

Procedure: To start with, an experimental and a control group of students were formed by the help of following tests:

(i) Raven's progressive matrices (Intelligence test)

(ii) Kuppuswamy's socio-economic status scale as modified by Shri Parthasarathy of Mysore University

(iii) An achievement test prepared by us.

These tests were used to make approximately two equal homogeneous groups, the Guided Open-ended Group (GOG) and the Traditional Laboratory Group (TLG) among boys and girls in the two colleges. The homogeneity of the groups was ascertained by calculating the F-ratios and t-values.

The two homogeneous groups worked for 38 contact hours in the laboratory during a period of one year. Many activities were done by the students on five different topics. The activities of one such topic, namely bending of light rays are briefly described below.

Students of guided open-ended group were given the following student-sheet at the beginning of the laboratory session.

Student Sheet

Roll No.: Time: 10 hours

College: Date:

I. Area	Light
II. Topic	To study the bending of light rays in optically transparent media
III. Pre-requisite knowledge	Laws of refraction, critical angle, parallex
IV. Apparatus and materials	Glass slab, prism, rectangular glass tank, hollow glass prism, convex lens, plane mirror, concave mirror, pins, travelling microscope, protractor, slits, liquid, light source, wooden board, spherometer.
V. Activities	Hint: Some of the possible methods to obtain refractive index are: 1. By finding the minimum deviation angle 2. By finding apparent depth 3. By critical angle method 4. By using hollow prism

5. By using a concave mirror
6. By adjusting the volume of the liquid, etc.

Use at least one method for each medium and describe the rest by discussing with other students.

VI. Evaluatory questions

1. Does the refractive index of a substance depend on the colour of light?
2. Does the refractive index of a medium depend on the shape of the substance?
3. It is possible to find the refractive index of glass using critical angle method by keeping the object in air? Explain.
4. Why do the parallel rays of light converge to a point after refraction through a convex lens?
5. On what factors does the lateral shift of the light ray depend while propagating through a glass slab?
6. List the factors which influence the maximum deviation angle in the prism?

VII. List further activities in this topic:

The students of guided open-ended group were asked to study this sheet very carefully. Some reference books were also provided to them. Relevant apparatus and materials were provided and explained to them. They were given freedom to choose the relevant activity and the necessary apparatus and materials. They were also allowed to choose the procedure they thought best.

Each student in guided open-ended group did 4 to 5 activities from the following:

I. Determination of refractive index of the transparent solid material by pin-method, shift-method, critical-angle method, spectrometer method and convex lens method; and
II. Determination of refractive index of transparent liquid by shift method, hollow-prism method, concave mirror method and liquid lens method.

They did these activities in five laboratory sessions of two contact hours each. At the end they were asked to discuss with others about their activities and findings.

It may be pointed out that although some guidelines or hints were given to the students, the experiment remained open-ended because:

(i) The methods adopted by students were different in doing the same activity. For example, in the hollow-prism method, some students adopted the pin-method to determine 'D' the angle of minimum deviation and 'A' the refracting angle and some others followed the spectrometer method. Similarly, while calculating the focal length, some students followed the plane mirror method, some followed the UV method, some obtained the image of an object at infinity and some obtained 'F' by shift method. Again while calculating the radius of curvature some used the spherometer, some used the protractor and some others adopted the Boy's method. Further,

(ii) The methodology of doing the experiment was their own.

(iii) Observational steps were not given to them.

(iv) Freedom was given for recording, tabulating and calculating their results in their own way.

(v) Different groups of students used the different transparent materials like rectangular glass slab, semi-circular glass-slab, rectangular glass tank with different quantity of liquid, lenses and mirror of different focal lengths etc.

The students of traditional laboratory group also did these experiments in five laboratory sessions of two contact hours each. They were provided with instructional sheets which contained the aim of the experiment, apparatus and materials required for the experiment, theory and procedure of the experiment, observational steps, tabular columns and essential formulae to calculate the required variables. Besides, experiments on bending of right rays in optically transparent media were demonstrated to them. Then they were asked to:

(i) Determine the refractive index 'μ' of glass by shift method using travelling microscope

(ii) Determine the 'μ' of water shift method by using travelling microscope

(iii) Determine the 'μ' of given material by using a convex lens

(iv) Determine the 'μ' of liquid by liquid lens method

(v) Determine 'μ' of the material of the prism by using spectrometer.

After the students of both the groups had done the experiments in five different topics for a period of 38 hours, they were given post-achievement and creativity tests.

Achievement Test

According to Good[5], achievement is an accomplishment or proficiency in a given body of knowledge and it is a measure of the students ability in terms of standardised test results. Hence achievement test is an evaluating tool used to measure the students' performance in the cognitive domain in the beginning and end of the programme.

In this project, post-achievement test comprises of suitable questions pertaining to the activities performed. The questions were finalised after administering them to 42 students and carrying out a detailed item analysis. Out of the 98 questions, originally administered to them only 76 questions were retained for the post-achievement test. Out of this 39 questions were at knowledge level, 22 at understanding level and 15 at application level. Care was taken to see that the questions covered only those concepts which were covered in both the groups. After administering this test, the answers were scored by using a scoring sheet and a scoring key.

Creativity test: Creativity test (verbal) developed by Professor Baqer Mehdi was used in our investigation. It helped in estimating the creative abilities of the students and in making high and low creativity subgroups.

Primary and Secondary variables

In this investigation the methods of performing practicals were considered as independent variables and the effect due to these methods on the acquisition of knowledge, understanding and application of facts, principles and concepts, development of certain creative abilities were considered as dependent variables. However there are other variables such as intelligence levels, socio-economic status levels, school achievement, age, sex, contact periods, interests of students and class instructor which may also contribute for the outcome of the investigation. So care has been taken to control these secondary variables. Accordingly the following null hypotheses have been made.

Hypotheses

It is hypothesised that no significant differences are identifiable between the GOG and the TLG:

Ho 1: In the mean scores of post-achievement test in Physics.

Ho 2: In the mean scores of post-creativity test.

Ho 3: With respect to their performance in post-achievement test when the different subgroups are made according to their intelligence levels.

Ho 4: With respect to their performance in post-achievement test when the different subgroups are made according to their socio-economic status levels.

Ho 5: With respect to their scores in post-achievement test when different sub-groups are made according to their creativity levels.

Ho 6: With respect to their scores in post-achievement test when different sub-groups are made according to sex.

Tools: The null hypotheses listed above have been tested by statistical methods. Null hypotheses Ho 1 and Ho 2 have been tested by 't-test' and the remaining hypotheses have been tested by 'F-test'.

Results

The results pertaining to testing of the above six hypotheses have been tabulated in the following tables.

Table 1

Experimental approach versus achievement and creative abilities

Hypotheses	Ability	Groups	Mean	S.D.	r	t-value	Significance level	Remarks
Ho 1	Achievement	GOG	56.00	52.14	0.9380	6.800	0.05	Significant
		LTG	32.70	30.80				
Ho 2	Creativity	GOG	150.00	5.960	0.9590	0.8300	0.05	Not
		LTG	149.9	5.080				

significant

df = degree of freedom = 45

The table shows that:

(a) Mean and standard deviation of GOG is greater than TLG on post-achievement test and post- creativity test,

(b) High degree of positive correlation (r) between the two groups, GOG & TLG,

(c) 'T' – value is significant at 0.05 level of significance for the null hypotheses Ho1 and hence it is rejected and

(d) 'T' - value is not significant at 0.05 level of significance for the null hypotheses Ho2 and hence it is accepted.

Creativity ability can be further divided into certain primary traits like fluency, flexibility and originality. These aspects have been carefully studied by making the following sub-hypotheses.

Ho2a : No significant differences are identifiable between GOG and TLG in the mean scores in post-creativity test.

Ho2b : No significant differences are identifiable between GOG and TLG in the mean scores of flexibility in post-creativity test.

Ho2c : No significant differences are identifiable between GOG and TLG in the mean scores of originality in post creativity.

The above three sub-hypotheses also have been tested by 't-test' and the result pertaining to these hypotheses are given in table 2.

Table 2

Experimental approach versus fluency, flexibility and originality

Hypotheses	Abilities	Groups	Mean	S.D.	r	t-value	Significance level	Remarks
Ho2a	Fluency	GOG TLG	59.28 44.00	129.8 89.81	0.9290	1.820	0.05	Significant
Ho2b	Flexibility	GOG TLG	38.60 31.60	73.94 51.99	0.7380	1.030	0.05	Not Significant
Ho2c	Originality	GOG TLG	28.85 18.90	107.6 64.78	0.8570	1.090	0.05	Not Significant

degrees of freedom = 45

The above table shows that:

Table 3

Results on the ANOVA of post-tests for the achievement by students of high and low levels of intelligence, socio-economic status and creativity

Variables	Hypotheses	Source	Sum of Squares	df**	Mean Squares	F-value	Significance level	Remarks
Intelligence	HO_3	Total Between Within	9408.75 7311.90 2097.85	51 3 48	– 2437.30 43.7050	55.77	0.05	Significant
Socio-Economic Status	HO_4	Total Between Within	8560.98 6038.06 2522.92	51 3 48	– 2012.68 52.5600	38.29	0.05	Significant
Creativity	HO_5	Total Between Within	11652.9 9780.77 1872.15	51 3 48	– 3260.25 39.0000	83.59	0.05	Significant

df* = degree of freedom = 45

(a) High degree of positive correlation between the two groups, GOG and TLG

(b) Mean and standard deviation of GOG is greater than those of TLG

Table 4

Results on the ANOVA of achievement by boys and girls

Hypotheses	Source	Sum of Squares	df**	Mean Squares	F-value	Significance level	Remarks
HO_6	Total Between Within	16457.7 11888.9 4568.70	91 3 88	– 3962.98 51.9170	76.33	0.05	Significant

df* = degree of freedom = 45

(c) 'T'-value is significant at 0.05 level of significance for the null hypotheses Ho2a

(d) 'T'-value is not significant at 0.05 level of significance for the null hypotheses Ho2b and Ho2c.

These results lead to the rejection of hypothesis Ho2a and acceptance of hypotheses Ho2b and Ho2c.

From the above table, it can be seen that 'F-values' for the hypotheses HO_3, HO_4 and HO_5 are significant at 0.05 level of significance and hence these hypotheses are rejected.

From the above table it can be seen that 'F-values' is significant for the hypothesis HO_6 at 0.05 level of significance and hence these hypotheses are rejected.

Discussion

The rejection of the null hypotheses HO_1 shows that the superiority of GOG over TLG in acquisition of knowledge, understanding, application of certain concepts and principles in Physics.

The results on the hypotheses on creativity are interesting. Though in general creativity aspects seem to be independent of the experimental approach, the rejection of HO_2a shows slight superiority of GOG over TLG in acquiring fluency, that is, in developing the fertility of ideas.

The rejection of null hypotheses HO_3, HO_4 and HO_5 shows the superiority of GOG over TLG in an achievement of cognitive abilities for students of both high and low levels of intelligence, socio-economic status and creativity test.

The results on the hypotheses HO_3, HO_4 and HO_5, also show that the two approaches guided open-ended and traditional laboratory are themselves not affected by both high and low levels of intelligence, socio-economic status and creativity of students, indicating that the experimental approach is equally applicable to all kinds of students. However the rejection of null hypotheses HO_6 shows that girls are superior to boys in their performance of post-achievement test.

The above observations lead us to conclude that (a) the guided open-ended approach is better than the traditional laboratory approach in the promotion of cognitive abilities like knowledge, understanding and application to students of both high and low levels of intelligence, socio-economic status and creativity, (b) the guided open-ended approach does not have any marked superiority over traditional laboratory approach in developing creativity, except in developing fluency aspect of creativity, where a marginal superiority is indicated.

Acknowledgement

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TEACHING THE EFFECTS OF FORCE AT GRADE LEVEL VI : TEXTUAL ACTIVITIES VERSUS HANDS-ON ACTIVITIES

Lalit Kishore
Project Director

Tushar Tamhane
Project Assistant
Science Resource Centre
KFI, Varanasi

The effects of force should be related to daily life situations and in technology. The students should be encouraged to identify the situations in the school environment wherein effects of force are visualised and to make a list thereof. This will enhance observation power of students.

Introduction

The effects of force form an important concept at the middle school level. In the NCERT syllabus for Class VI, the concept comes under the topic of "Motion, Force and Machines" (Lahiry et. al. 1987). After the idea of force has been introduced to the students, it is quite worthwhile to introduce the effects of force through some activities to give students the first-hand feel of the same.

Though the NCERT book Science: A Textbook for Class VI has given some activities to introduce the concept but common experience of teachers indicates that the activities described in the textbook are not dramatic and challenging and children find them common place and dull. Therefore it was thought that some alternate activities in which more dramatisation, along with some hands-on aspect, connected with assembly and construction of the activities are there, should be developed.

Objectives

Before the topic is dealt within the classroom, the previous knowledge of students on the concept of force and kinds of forces should be tested and reinforced. The teaching of the topic "Effects of Force" should lead to attainment of the following instructional objectives:

1. To provide hands-on experiences for learning effects of force.
2. To apply the concept to daily life situations.
3. To explain some simple events on the basis of effects of force.
4. To use the effects of force to design some simple (low-level) technological devices.

Textual Activities

The activities as described in the NCERT textbook are shown in Table 1.

Table 1

Name of the activities	Short description	Major conceptual experience
Change in speed	a. Opening an umbrella against the wind. b. Hitting glass marble gently and then strongly.	Pushing back by the wind and decrease in speed. Observing the difference in speed.
Change in direction	Dropping of a cardboard piece and striking it with hand in air.	Due to striking the cardboard changes direction in the mid-air.
Change in shape	i. Pressing dough ii. Pressing sponge iii. Pressing tomato iv. Hammering a strip of iron v. Extending a spring	The shape of all the objects changes on applying force.

Summary of NCERT Textbook Activities on the Concept of "Effects of Force"

Short Critique

Even a cursory look at these activities would indicate that these cannot be effectively used as demonstrations or hands-on experiences for children as they are more of daily life applications which children keep on experiencing quite frequently. Such classroom activities which are mostly discussed orally do not excite the children.

The activities mentioned in Table 1 do not provide the opportunities for children to design the activities themselves through assembly and construction which are essential components to sustain interest and make learning of science a joyful experience for children.

Alternative Method

As an alternative to the above-mentioned activities, some new activities were envisaged and implemented to provide children with some experience in construction and assembly before extracting the concepts from the activities which children found quite absorbing.

Before a sample activity is given in some detail followed by other activities in brief, it would be worthwhile to mention that mainly the rubber bands were used for imparting the concepts related to "effects of force". The concepts were further simplified into sub-concepts to provide a variety of experiences. The conceptual schemes of

S. No.	Name of activity and major concept	Sub-concepts	Short description of assembly'	Remarks
1.	Change of shape	(i) Elongation (ii) Twisting (iii) Compression	Rubber band tied to a thread which passes over an improvised pointer-pulley arrangement A rubber band tied to a cycle spoke with free end bent into the shape of '8'.	Extension investigative activities by increasing force in steps. Making a rubber band newton-meter.
2.	Imparting motion	(i) Setting a body into motion for rest (ii) Distance travelled increases with the increase in force.	Rubber-band* projectile	Investigative activity: Force vs. distance moved.
3.	Destroying motion	Resistive force	Making a wheel** roulette and stopping with lever brakes	
4.	Increasing speed	Pulling a match box trolley and again pulling it with a newton-meter.	Trolley is made with match box and plastic buttons***	Investigation: force vs. speed
5.	Change of direction	Curvilinear motion	Rotation of two objects—one heavier than the other—tied by a string and passing through a straw piece which is rotated	Qualitative investigation is possible.

the alternate activities are summarised in Table 2.

Table 2

*Kenneway (1980) ** Gupta (1989) *** Gupta (1990)

Exemplary Activity

The activities were prepared in the form of activity sheets. An example of such a sheet is given below.

Tools: Hammer or big stone or brick piece, scissors.

What is to be done:

1. Take the wooden piece and drive in a nail or an alpin near its one end.
2. Now take another nail or alpin and fix it 5 cm away from the first nail.
3. Take a refill piece and pass it over the 2nd alpin or nail.
4. Fix the hook near the other end of the wooden piece.
5. Take the rubber band and tie it to one end of

the twine thread.

6. Pass the twine thread over the refill piece giving it one turn around the refill piece.
7. Pass the twine thread through the hook and tie it to the U-clip or jam clip.
8. Take the thick paper piece. Trim its corner on one end to make a pointer out of it.
9. Near the other end of the pointer put a small cut and pass it over the refill piece so that it remains fixed.

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Activity: Put the twine thread from the U-clip

a. What do you observe?

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b. What do you conclude from this activity?

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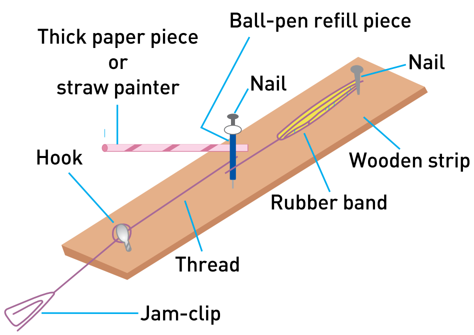
Extension activity could be the study of relationship between load and extension of the rubber band.

Effects of Force

Sub-Activity 1

Sl. No.	Material	Specifications	Quantity	Remarks
1.	Wooden piece (Piece of a broken wooden scale)	10 cm × 3 cm	1	
2.	Ball-pen refill piece	2 cm	1	
3.	Pin or thin nail	Alpin	2	
4.	Thread	Twine, 15 cm	1	
5.	Thick paper piece	Chart paper 5 cm × 0.3 cm	1	
6.	Hook	Picture frame hook or curtain hook	1	
7.	Clip	U-clip or jam clip	1	
8.	Rubber band		About 2	



to 4 cm long 1

In Conclusion

A simple action research in which the textbook described activity and learning through activity sheet as described above was given to students and their reactions were elicited in a non-threatening climate showed that children over-whelmingly favoured the latter (N=55, p=0.01)

Thus, in order to make the learning of the concepts related to the topic "Effects of Force" effective, it should be kept in mind to provide hand-on constructive and manipulative experiences to children. It would be still better if children are able to do some investigations in the conceptual areas under consideration. This will provide children a feel for the processes of science.

Furthermore, the effects of force should be related to daily life situations and in technology. The students should be encouraged to identify the situations in the school environment wherein effects of force are visualized and to make a list thereof. This will enhance the observation power of student.

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EDUCATION IN PHYSICS FOR RURAL CHILDREN

Surjeet Singh
87, Phase-7
SAS Nagar
Punjab

Educationally, we must know that concepts of physics grow gradually. There cannot be light all at once. For example we all know that force is a mass of an object multiplied by its acceleration. But do you know how long it took Newton to reach at that simple equation. And before him, Galileo's ideas on motion of objects. It took centuries for the common man to accept the idea of zero. Light is a wave was not accepted for a long time. Einstein was never awarded the Nobel Prize for his ideas on relativity.

First, we note that our target is rural children. We shall look at the deficiencies of physics curriculum planning which I had experienced as an administrator. Then we shall make a few assumptions for designing a physics course for the school children of rural areas. But before these postulates, we must look into the rural conditions as prevalent today. And also, what is physics?

The last question appears ridiculous? Who does not know that physics is a study of matter, energy and the effects of energy on matter. I recall the topic being discussed is 'physics education in rural areas'. The word 'physics' qualifies the noun 'education'. I think that there are three features of physics. One, the content of physics by which I mean facts, concepts, principles, models, i.e., hypotheses, equations relating different physical quantities. These equations represent the epitome of experiences over centuries. We can describe facts by observation, check them by experiments, i.e., acquiring information, and explain them by a theory. The second feature is the method of physics. No one method is known to us. But some steps of the method can be noted, namely:

1. Observation and measurement
2. Comparison
3. Drawing inferences (discovering a relation between physical quantities)
4. Interpretation.

The third feature is the values of physics which constitute the scientific temper. Some values of physics are:

1. To be fair
2. To keep mind open
3. To discard superstitions
4. To develop the spirit of enquiry.

The only way to learn these values, is through the example and practice by the teachers in the classroom.

Science and Basic Education

Early attempt to teach science including physics is incorporated in Basic Education. Mahatma Gandhi proposed Basic Education for rural India. Its main feature was craft. All subjects, including physics, were correlated with craft. Most people came to regard this Project as designed for the backward classes. It failed educationally also. The difficulty was in the correlation. Once I discussed the correlation of humidity (a topic of science) with weaving craft. The science teacher described the co-relation in terms of experiments of the composition of air by volume. Was it a correlation? Any villager knows that the presence of water vapours in air affects the strength of cotton fibre.

Physics Education and Human Resource Development

The USSR launched a satellite in 1954. The Americans and the Britishers were spurred to think on improving the quality of physics education. In mid-sixties India felt the need of science education when China invaded. For human resources development, one priority sector was basic education. The education policy devotes one para or so, to science education. The policy requires to develop manpower with scientific temper. The first step is to frame the syllabus for different classes. But who frames the syllabus? A school teacher? A college teacher? A university teacher? A teacher-educator? Perhaps, all together. A college teacher regards each student as a potential doctor, an engineer or a scientist. A teacher-educator thinks that the classroom teacher has a limited teaching ability to pass on the knowledge of physics owing to the varied nature and nurture of the rural students. This is an inherent limitation. The syllabus is finally agreed. But the issues, for example, whether the concept of speed or velocity be introduced in the primary courses are hardly discussed in the light of the educational needs of the society. These issues are crucial for classroom teachers.

But what are the rural conditions? In general the conditions of the rural people can be described by their characteristic poverty, illiteracy and social backwardness. Apart from the superstitions, the non-availability of safe drinking water and epidemic of common diseases are hard facts of rural life.

We know that 77% of our population is rural. It is broadly agriculture labour or self-employed in non-agriculture. Both sections are poor. They differ in the degree of poverty. So, poverty factor must be considered while planning physics curriculum for rural children. It does not mean that physics is different for rural people. The ideas of physics are the same but we can give a certain level of concept which is really useful for improving their quality of life.

Literacy

About mid-eighties, the literacy was 36% in India (47% M; 25% F). Again the school enrolment was 54%. This means 46% children did not join any school and are likely illiterate parents of the next generation. This figure is significant. It implies a constraint on physics curriculum. It is a known fact that for every 10 children who join a school, 7 drop-out before they reach high school. So physics must not scare them.

Social Backwardness

Added to this is the stigma of the class system which has developed a permanent set of contempt for one status below the other. Not only that, the top class exploits the lower class. For example, many taboos, superstitions and traditions are simply to perpetuate the class system. The atrocities on Ambedkar are an example. The stigma sticks to a class like a scar on a body. Physics must help in breaking this habit of thinking.

Educational Facilities

In many primary schools in rural areas, the classes are held in the shade of a tree, may it rain or storm. Operation Blackboard is an index of the dismal educational conditions in schools. The teaching of physics must be appropriate to these conditions.

Model Schools

Is the idea of model school educationally sound? What is model about them? A particular dress; enormous fee and funds; a heavy bag. Middle class families consider it a privilege to send their children to model schools. It appears to be anathema in an Indian society, particularly in rural areas. The idea exploits the middle class commercially. Kothari Commission never recommended the idea. Anyone can find that a model school child learns the facts of science without comprehension. For example, a model school child knows ebullition as boiling of a liquid. But what is boiling? He may not understand. Since the young mind is very fertile and sharp, he can remember the facts by heart. The parents are satisfied. And here lies the tragedy. Do you want this kind of physics for the rural children? Perhaps this physics is not suitable for rural children. This is the kind of liberal education which no doubt broadens the mind but has limited employment opportunities especially for villages. I call this 'babu education' which alienates the children from their own rural society.

Science Education Programme and Experiences

The NCERT prepared the physics curriculum for different classes. It was felt that the teaching of physics required doing experiments. And for that, the idea of science kit was accepted. Thus the science kit was the mainstay of the Project, 'Science is Doing' was the slogan.

To start the programme, the UNICEF gave some aid and science kits to the pilot schools. This kit contained a few tools. The purpose was to let teachers innovate, improvise and design their own experiments, if and when required, to explain or describe a concept of physics. But the teacher never accepted the idea of 'doing' in practice due to the social prejudices against doing work with hands.

Once, on my visit to a rural school, I found that the science kit was kept locked away from the school. The teacher said, "Sir, the students spoil the kit items. So, I do not allow them to touch these." Thus the provision of a kit did not materially change the style of teaching towards 'doing' science in the classes. It was you-read-method.

Educationally, curriculum planning suffered from inadequacies. For example, the idea that solid consists of tiny particles, called molecules, was demonstrated in the class with the help of marbles in a tray. At the end, to a question, what is a molecule? Quick came the answer 'Marble, Sir'. The classroom teacher was satisfied.

Again, one objective of the Project was to develop an enquiring mind. This implies answers to the questions raised by the children in the classroom. But we all know that no teacher likes questions in the classroom. Indeed the teacher is oblivious of this objective. The spirit of the programme seems lost somewhere.

Lastly, the School Board played little role in the planning of science curriculum. I have an experience. In the middle school examination a question was set in the science paper: Describe the gold leaf electroscope and label its parts on a sketch. One boy, in a pilot school, made the diagram as he had seen in the science kit, i.e., rectangular shaped. The teacher awarded him zero mark. The sketch did not conform to the bell-jar shape given in the textbook prescribed by the school board.

Further, the inability of States like U.P. to supply the science kits gave forth the idea of using environmental situations and local resources. The 'doing' element was retained. But this innovation, too, did not succeed. It was a difficult challenge for the teachers.

So my experiences convince me that any idea for rural physics education will find acceptance only if viewed in the light of its usefulness, rural needs and the teaching abilities of the rural teachers.

Assumptions

Considering the above discussion, we make three assumptions for designing a physics course:

1. Primary education is likely to be the whole education for most of the Indians for their whole life. Very valid, even after 45 years of independence, we have not been able to fulfil the constitutional obligation of providing elementary education to all school-going children. That is why the added problem of the swelling number of illiterates; increasing population, poverty and social backwardness. So, physics must be useful and meaningful.

2. Educationally, we must know that concepts of physics grow gradually. There cannot be light all at once. For example, we all know that force is a mass of an object multiplied by its acceleration. But do you know how long it took Newton to reach at that simple equation. And before him, Galileo's ideas on motion of objects. It took centuries for the common man to accept the idea of zero. Light is a wave was not accepted for a long time. Einstein was never awarded the Nobel Prize for his ideas on relativity.

3. The laws of the nature are the same for rural people as for urban people. Also, rural needs are not different from urban needs. The basic requirement is 3 R's. The science at

most can be descriptive and/or experimental within the social and physical environment of rural people. Observation and measurement should be at the heart of the classroom lessons. So, I postulate that the development of the descriptive ability is the foundation of physics education and must be dominant in the teaching of physics.

Physics Course

With these assumptions, we propose a physics course for the primary schools. It is open to be accepted or rejected or altered to suit rural needs. We can choose our own path, i.e., course, method and values of physics provided we keep to the national goals and the rural needs. The path will shine if we follow Buddha's advice – observe yourself and think in the light of your own observations.

1. Some properties of matter and forms of energy
2. The effects of energy on matter i.e., a substance expands: a solid melts: a liquid boils. The concept of temperature.
3. (a) Machines e.g., lever and wheel

   (b) Thermometer
4. (a) The measurement of distance, mass, time and temperature.

   (b) The idea of speed as distance over time (distance-time relation).

The suggested topics have a tremendous scope for teaching physics as discussed in the paper. Useful and smart, and not fat, courses can be popular. The beauty lies in the classroom planning. And this implies support for teachers. It is the power of the argument and not the argument of power which wins the people to your corner. Therefore the concepts of physics should be educationally researched, experimented and debated well. Here lies the role of the IAPT which can set up a few consultancy centres of physics education to provide opportunities for meeting of teachers and specialists.

The Education Experts

'Know thyself', Socrates said. We, as technical experts, can be strong forces to bring about educational change. Non-experts give ideas which are often not fruitful. Recently, an idea of a Rural Model School was floated to prevent standards from deteriorating at +2 level. I fear this idea is conventionally to look at the problem upside down and that too laterally.This thinking disregards the foundation, i.e., the primary schools upon which the whole structure of education and in turn the welfare of the society depends. We know that the political idea of Adarsh Schools in rural Punjab did not succeed as expected.

Also, the imported idea of science kit introduced without a debate on its educational potential vis-à-vis rural conditions did not yield the desired results. Again we know that under the UNICEF and UNDP Programme a large stock of science apparatus and equipment was distributed to the Teacher's Training institutes. The stock contained very ordinary items like wooden metre rods, test-tubes, beakers, etc., for which abundant, cheap and best quality substitutes were available in India at Ambala, a town known for its scientific educational industry. Not only that, the electrical equipment after sometime became junk: the Bakelite was not suited to tropical conditions and also the pin points were rectangular unlike cylindrical in India. But none was made accountable for this mistake.

In conclusion we may say physics should largely be descriptive or experimental. The curriculum must be smart and flexible especially for elementary education. The methods and values of physics must form part of the classroom lessons. And this requires the support to the rural teachers. For this support, the centres of Physics Education should be set up by voluntary organisations and teachers' unions. The school Boards can also be approached to set up similar centres where the subject experts debate on issues and resolve the problems of curriculum development.

GRAVITY IN ACTION

L.S. Kothari
71, Vaishali Enclave
Pitampura, Delhi

You might have wondered why objects when released from a certain height fall down on the ground. When you throw a ball up it does not continue going up, but soon comes to a halt at a certain height and then begins to fall. As it falls it gains speed. If we release two bodies of different masses from a certain height, say the roof of a house, will they reach the ground at the same time or at different times? This question is not at all easy to answer. If you drop a piece of paper and glass marble from a certain height, the marble will hit the ground much before the slip of paper reaches there. Even if we take objects of similar shape the answer is not easy. You might have noticed that larger rain-drops fall much faster than smaller ones – though all drops are spherical in shape. Even if we take two identical spheres, say one made of lead and the other of wood, can one say that they will fall together when released from a height simultaneously. The great Greek philosopher Aristotle (384 -322 B.C.) firmly believed that heavier objects fall faster than lighter objects of identical shape. No one questioned his judgement for many centuries and probably no one ever tried to verify whether what Aristotle said was correct.

The great Italian scientist Galileo Galilei (1564–1642) was amongst the first who wanted to experimentally test many of the ancient beliefs. He is rightly regarded as the father of modern scientific method. It is said that he dropped two identical spheres, made of different materials – one heavy and another light – from the top of the Leaning Towers at Pisa. He found that both the spheres reached the ground at the same time. This was a great discovery – objects fall to the earth at the same rate independent of their mass. You will note that this simple fact which we now take for granted is not at all obvious and took many centuries to get established.

We earlier considered examples of a glass marble and piece of paper and also raindrops of different sizes. These are observed to fall at different rates. How do we reconcile Galileo's observations with ours? In the case of certain objects like paper, feathers, parachutes or small spheres like rain- drops air plays a dominant role and changes the rules of falling bodies.

Kepler's Laws

The great Danish astronomer Tycho Brahe (1546-1601) is unparalled in the history of science. With naked eyes and instruments designed and built by him for measuring angles, he spent his entire life making precise measurements of the positions of celestial bodies. He accumulated accurate and vast data. As he did not have much talent in mathematics he could not himself make much use of the vast data. His Austrian assistant Johannes Kepler (1571-1630), an outstanding mathematician, analysed the available data. He provided confirmation for the Copernican model of the solar system, according to which the planet revolved around a stationary sun. Kepler formulated three laws for planetary orbits. These are:

1. Planets revolve round the sun in elliptical orbits.

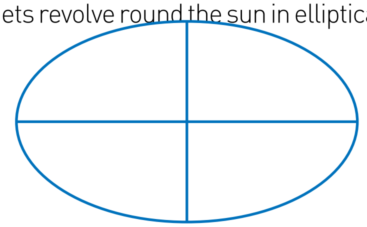

Fig. 1

2. An imaginary line drawn from the sun to the planet sweeps equal area in equal time (Fig. 2a, b).

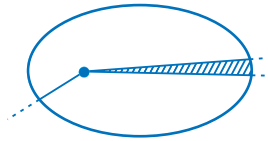

Fig. 2a

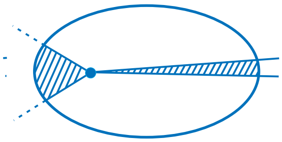

Fig. 2b

3. The squares of the times required by the planets for a complete orbital revolution about the sun is proportional to the cubes of their average distances from the sun (See Table 1).

These laws were discovered from observed data and no justification could be provided for them.

Table 1

Planet	T (Period in years)	R (Distance from the sun is terms of earth sun distance)	T^2	R^3
Mercury	0.241	0.387	0.058	0.058
Venus	0.615	0.723	0.378	0.378
Earth	1	1	1	1
Mars	1.881	1.523	3.276	3.533
Jupiter	11.862	5.203	140.7	140.85
Saturn	29.46	9.564	867.9	874.8

Law of Gravitation

The year Galileo died, Isaac Newton (1642-1727) was born in England. He is ranked amongst the world's top scientists for all times. He contributed in a major way in many fields of science. You may have heard of the three basic laws of motion which go by his name. He demonstrated that white light is composed of seven colours. He was one of the persons to develop the whole field of calculus in mathematics. He also gave the law of universal gravitation. We will discuss this last topic in some detail here.

There is a story often told about Newton. It is said that once while he was sitting in a garden, he saw an apple fall from an apple tree. This set him thinking as to why things fall to the earth and not fly away. He conjectured that just as the earth pulls the apple towards itself, all matter must attract other matter. But what should be the law of attraction? How does the attraction depend upon the masses of the bodies and how does it depend upon the distance between them? It was the genius of Newton that form a simple observation of a falling apple and the laws of Kepler, that were known to him, he obtained, what we now call as Newton's law of universal gravitation. According to this law two mass M_1 and M_2 attract each other with a force proportional to the product of their masses and inversely proportional to the square of the distance R, separating them. That is, the force

$$F \alpha \frac{M_1M_2}{R^2} \quad \text{or} \quad F = G\frac{M_1M_2}{R^2} \qquad \text{........... (1)}$$

where G is the constant of proportionality and is called the gravitational constant. If F is measured in newtons, M in kilograms and R in metres, then

$G = 6.67 \times 10^{-11}$ ← m^3 / kgs^2

Before we look into the consequences of this law, let us see what impact it had on the thinking of the times.

As we mentioned above, experimental science, in the modern sense, started with Galileo, only a few decades before Newton. A few laws of Nature had been discovered from observations made in the laboratory or outside. There were no reasons to assume that the laws so discovered would also hold in very different situations. Hence, when Newton showed that Kepler's third law followed from his law of gravitation, it has great impact on the thinking of the times. It established that the laws discovered by man from his observations on the earth also applied to the heavens. It is this which made the entire universe amenable to study by man.

Falling Bodies

Let us now come back to the problem with which we started, that of falling bodies on the earth. Let the radius of the earth be R and its total mass M. If we have a body of mass m close to the earth's surface, the force exerted on it by the earth will be

$$F = \frac{GMm}{R^2} = gm \qquad \text{........... (2a)}$$

Where $g = \dfrac{GM}{R^2}$ or $M = \dfrac{gR^2}{G}$ .... (2a)

This force is directed towards the centre of the earth. Here g is a constant. Thus the force of attraction on a body of mass m, near the surface of the earth is directly proportional to its mass m. We now involve Newton's second law of motion: The force acting on a body is equal to the product of its mass and its acceleration, and is directed along the acceleration written mathematically it is

$$F = ma \qquad \text{........... (3)}$$

where a is the acceleration. If we are dealing with the earth's force of gravitation then from equations (2) and (3) we have

$F = gm = ma$ .... (4)

i.e. $a = g$

The quantity g is called acceleration due to gravity. Eq. (4) implies that the acceleration experienced by anybody falling under gravity is independent of the body's mass. Hence all falling bodies fall with the same constant acceleration, g.

It is important to note that we have nowhere talked of the atmosphere and the influence of air on falling bodies. Eq. (4) holds only when the resistance offered by air to a falling body can be neglected.

The value of g can be determined by studying falling bodies. It is nearly

$g = 9.8\ m / s^2$

The value of g varies slightly from place to place on the surface of the earth, since it is not a perfect sphere.

We note from Eq. (2b), that if we can find the radius of the earth, knowing g and G, we can easily find the total mass of the earth. The radius of the earth had already been determined by the Greeks by measuring the lengths of shadows cast by objects, at two different cities whose distance was known. The presently accepted value of earth's radius is 6371.02 km. Taking roughly

$R = 6.4 \times 10^5$, we find

$$M = \frac{gR^2}{G} = \frac{9.8 \times (6.4)^2 \times 10}{6.67 \times 10^{-11}}\ km$$

$= 6 \times 10^{24}$ km.

Did you even think what could be the mass of our earth and how it could be estimated? Is it not a wonder that by studying falling bodies, we can estimate its mass. It is instructive to determine the average density of the earth. Since we know its mass and its radius, it is easy to calculate the density.

$$\text{Density } P = \frac{\text{Mass}}{\text{Volume}}$$

$$= \frac{\text{Mass}}{4/3R^3} = \frac{3gR^2}{4GR^3} = \frac{3g}{4GR}$$

$= 5.5 \times 10^3\ kg/m^3$

You know that the earth rotates about its axis once in 24 hours. This is what causes day and night. We live on the surface of the earth. What is the speed with which this surface is moving? This would be the speed with which we go round, without even being aware of it (Fig. 3). Let us calculate this speed. It will be

$$\text{Speed} = \frac{\text{Circumference}}{\text{Time of one rotation}} = \frac{2\pi R}{24\ \text{hours}}$$

$= 0.47$ km/s

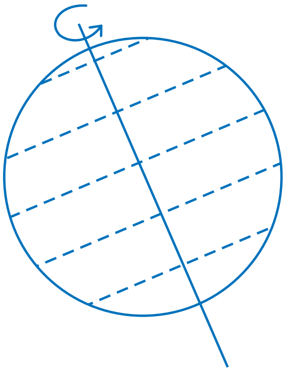

Fig. 3

i.e., nearly half a kilometre per second or 1800 km/hr. This is almost the speed of present day jet planes.

If we are travelling at such a high speed sitting on a rotating sphere, why are we not thrown off into space? The answer is that the attraction due to gravity is much stronger than this and keeps almost tied to the ground. Can we set ourselves free from this grip of the earth? Yes, we can. If the kinetic energy of a body is equal to its potential energy on the surface, then it can escape from the gravitational attraction. We can write the condition for a body of mass and speed as

$$\frac{1}{2}mv^2 = \frac{GMm}{R}$$

$$\text{or } v^2 = \frac{2GM}{R} = 2gR$$

.... (5)

This gives v = $\sqrt{2gR}$ = 11.2 km/s.

If a body should have a speed equal to or greater than about 11.2km/s, it will be able to get away from the earth's attraction. If the speed is lower, it will go up, stop and come down again.

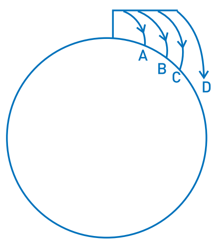

Fig. 4

The Moon

Unlike some large planets like Jupiter and Saturn which have a large number of moons (12 and 9 respectively), our earth has only one, but what a beautiful one! It goes round the earth in 27.3 days. The period of rotation about its own axis is also the same. This is why from the earth we see only one face of the moon. The other side is hidden from us. (We now have photographs of the other side too, taken by satellites which went round the moon). The moon goes round the earth because of its gravitational attraction.

Consider a tail tower over the surface of the earth. If a ball is thrown horizontally from the top of the tower, it will gradually come down and fall down on the surface of the earth, say at A (Fig. 4).

If we throw another ball with greater horizontal speed, it will fall at some point B, farther from the base than point A. if we were to throw a ball with such a speed that the surface of the earth bends by as much as the ball falls towards the earth, then it will continue to move in a circular path without ever falling on the surface. The moon too is falling towards the earth like any other object, but since it also has a tangential speed, it fails to hit the ground, and keeps moving in a circular orbit.

Since we know the period of revolution of the moon around the earth, we can calculate its distance from us. Let M be the mass of the earth and R the distance of the moon from the earth, then

$$\frac{GMe}{R^2} = \frac{v^2}{R} = \frac{(2\pi R)^2}{T^2}\,\frac{1}{R} = \frac{4\pi^2 R}{T^2} \quad \text{............... (6)}$$

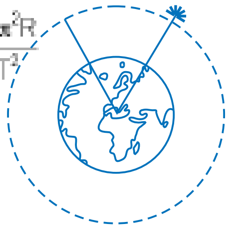
Fig. 5

Here T is the period of revolution of the moon around the earth. This equation leads to

$$R = \sqrt[3]{\frac{GMeT^2}{4\pi^2}} \quad \text{or} \quad T = \sqrt{\frac{4\pi^2 R^3}{GMe}} \quad \text{............. (7)}$$

(Note that Eq. (7) is the mathematical form of Kepler's third law). Substituting the values of G Me and T in Eq. (7) we get

R = 383000 km

which is nearly 60 times the radius of the earth. (The more correct value is 384400 km).

Eq. (7) will also hold for artificial satellites. For example we can calculate the height above the earth's surface where a geostationary satellite is established. Since these satellites appear stationary with reference to a particular place directly below on the surface of the earth, they must also revolve round the earth with a period of 24 hours. Hence using Eq. (7) we find, R = 42200 km. Subtracting from this a distance equal to the radius of the earth (=6400 km), we get 35800 km as the height of a geostationary satellite from the earth's surface (Fig. 5).

Let us now calculate the value of g on the surface of the moon. Using the parameters of the moon given in Table 3 and using Eq. (2b), we find

g_{moon} = 1.66 m/s^2

which is nearly 1/6th of the value of g on the earth.

Table 2

Earth

mass = 5.976 × 10^{24} kg

mean radius = 6371.02 km

(rounded off to 6400 km)

Moon

mass = 7.35 × 10^{22} kg

mean radius = 1720.2 km

Distance of the earth from the sun = 149.6 × 10^6 km

Distance of the moon from the earth = 0.3844 × 10^6 km

This means that moon's hold on objects on its surface is much weaker than that of the earth. For the same effort, a man may be able to jump six times the height he jumps on the earth.

The escape velocity (Eq. 5) on the surface of the moon is

$$v_{moon} = 2.42 \text{ km/s}$$

which is almost 1/5th of what it is on the earth.

Centre of Mass

In deriving Eq. (7) for the moon going round the earth, we had to define the distance between these two large objects. From which point on earth to measure this distance and up to which point on the moon? Law of gravitation implies that there should always be one point in everybody at which we can take its total mass to be concentrated, so far as its interaction with other objects is concerned. This point is called the Centre of mass. For a uniform sphere, the centre of mass is at its centre.

Let us considering a simple but interesting example. Take a stiff card and draw on it (or trace) the figure of the bird shown in Fig 6a. On both A and B place a 50 paise coin and attach it there with the help of cellotape. Turn the bird up-side down so that the 50p coins are now on the lower side. You can now balance the bird from its beak on your finger tip (Fig. 6b). This is because the centre of mass of the object is near its beak.

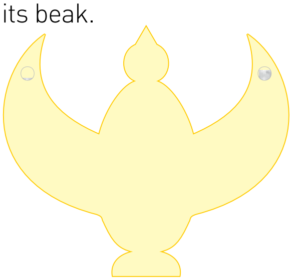

Fig. 6a

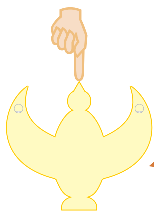

Fig. 6b

Consider a small table lying on a flat surface whose inclination to the horizontal can be varied. The force of gravity of the earth acts on the centre of mass of the table along a line perpendicular to the earth's surface (and pointing towards the centre of the earth). If this line intersects the surface on which the table is resting (Fig. 7) at some point inside the area defined by the four legs. The table will be stable. However, if the point of intersection lies outside this area the table will topple over.

You can try a simple experiment yourself. Stand close to a wall with one foot and one arm in contact with it. Try to bring the other foot in contact with the one in contact with the wall, without seeking any support. You will find that this cannot be done. This is because our centre of mass is close to the navel and if both feet are in contact with the wall, the vertical line drawn through our centre of mass will be outside the support base and the body will become unstable. When we stand in the normal posture, the vertical line through our centre of mass lies between our feet, and our body is stable (Fig. 8).

If you have climbed a hill or a steep slope, you must have observed that one has to bend forward. This is again to ensure that the vertical line through the centre of mass passes through the support base.

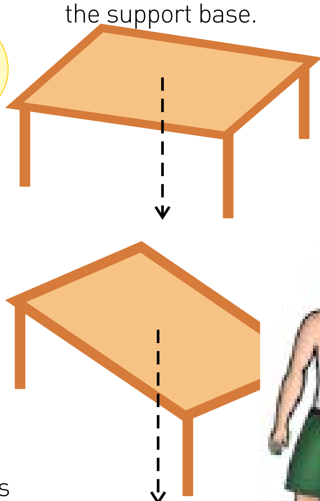

Fig. 7

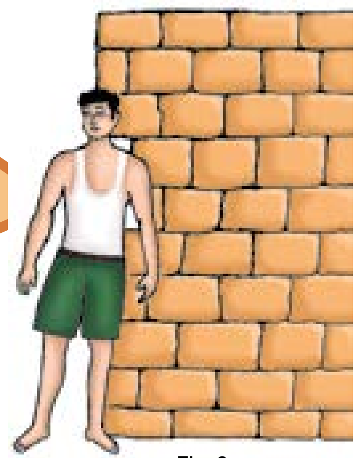

Fig. 8

Our Atmosphere

As you know, our atmosphere consists of mainly three gases – nitrogen, oxygen and carbon-di-oxide (also water vapour). Table 3 gives more details of the constituents. Life on earth has evolved only because of the relatively large abundance of oxygen. If we examine the composition of the Universe, we find that hydrogen and helium dominate over all other elements. Then how is it that our atmosphere has so little hydrogen and helium?

Table 3

Gas	Percentage	Molecular Weight	Average (rms) speed at room temperature
N_2	78	28	0.52 km/s
O_2	21	32	0.48
C_2O	0.03	40	0.432
Nobel gases	0.9	-	-
H_2	Trace	2	1.93

Let us assume that our entire atmosphere is at a uniform temperature of say 27^0C (300 kelvin). The average energy of nitrogen molecules will be the same as that of molecules of other gases, e.g., O_2 or H_2,...This is technically referred to as the law of equipartition of energy. However, this does not mean that the average speed of N_2 molecules will be the same as that of H_2 molecules. We know that the kinetic energy E of a body is related to its speed by the relation

$$E = \frac{1}{2} mv^2 \qquad \text{.............. (8)}$$

where m is the mass of the object. For different gases at room temperature the average speeds of molecules are given in Table 3.

We note that the average speed of hydrogen molecules is nearly 2 km/s. In a gas one will find molecules with all possible speeds ranging from almost zero to extremely large values, may be hundreds of km/s. If the average speed is around 2 km/s the fraction of molecules having speeds exceeding the escape velocity (11.2 km/s) will be substantial. Hence there will be fair change of their escaping from the earth's hold. On the other hand if we consider oxygen molecules, their average speed is around 9.5 km/s. Thus the fraction of molecules with speeds exceeding the escape velocity will be small. This partly accounts for the present composition of our atmosphere.

We saw that on the surface of the moon, the escape velocity is only about 2.5 km/s. Because of this all gases have escaped from its surface, and there is no air on the moon. Hence no life can exist there. Even two astronauts will have to communicate with each other through radio waves – there is nothing like sound there.

Gravity in Action

Many phenomena which we observe on our earth are a direct consequence of gravity, though in some cases the connection may not be obvious. Air pressure, water pressure inside oceans, tides, water falls are a few examples. Let us examine them in some detail.

Air Pressure: Inside a quiet room we hardly feel the air around us. But the pressure it exerts on our body is equivalent to a water column of 10 m height. How is it that we are not crushed

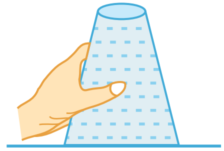

Fig. 9

under so much pressure? This is because, there is the same air inside our bodies and the two forces from inside and outside just balance. An easy way to demonstrate this pressure is the following: Take a tumbler and fill it with water upto the brim. Slip a card over the mouth of the tumbler so that it is fully covered. Hold the tumbler in your hand and place the palm of the left hand over the card. Quickly turn the whole thing upside down. Remove your left hand from under the card.

The card should stick to the tumbler and not fall off. This is because the force exerted on the card by the air from below is much greater than that exerted from above by water inside the tumbler.

Tides: The gravitational attraction of the moon cause tides in the oceans. High tides occur both in the part of the ocean directly towards the moon as well as in the ocean directly opposite. If the sun happens to be close to the direction of the moon, then the tides are very high.

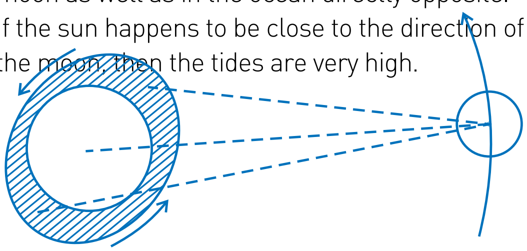

Fig. 10

Water Falls: You may have seen some water falls. They are usually a very grand sight. Some are seasonal and some perennial. When there is a sudden change in the level of the ground along which a river flows, water falls develop. Water falls from a higher level to the lower level because of gravity. In Europe many small water falls were utilised to drive flour mills. Large water falls can be used to generate electricity.

Dams: These days we used lot of energy in the form of electricity. Major electric power in our country is produced in power stations burning coal. Coal stocks are limited and hence lot of attention is being given to nuclear energy and renewable energy sources like solar energy and hydro-electricity. To generate hydro-electricity, a high dam is built across a river when it is flowing among mountains or raised ground. You must have heard of Bhakra and Nangal dams in Punjab and Nagarjuna Sagar dam in Karnataka. Water is allowed to fall from near the top of the dam, to lower levels. This falling water acquires lot of kinetic energy due to gravity, which can be used to run electric generators.

Pendulum: Man has learnt to make use of gravity in various ways. Galileo, while sitting in a Cathedral observed that the period of oscillation of a chandelier hanging from the roof, did not depend upon the amplitude of oscillation. This was a very important discovery, and led to the concept of present day pendulum. It is very easy to set up and study a pendulum. It is just small mass attached to a string, which is died at the other hand to a rigid support. The mass must be free to oscillate. The time-period of a pendulum is defined as the time required to complete one oscillation say from O to A to B and back to O (Fig. 11).

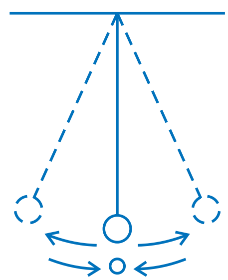

Fig. 11

The time period is dependent on the length of the pendulum and not on the amplitude of oscillation. At one time, pendulum clocks were very common in homes. They have now been replaced by battery driven electric clocks. We have considered here a few examples where gravity is seen to operate. As a matter of fact, life in the universe exists because of this or more generally the sun and the stars and the planets are there because of this universal property of all matter.

NUCLEAR TECHNOLOGY AND PUBLIC HEALTH

I.O. Essien

Department of Chemistry and Biochemistry
University of UYO, P.M.B. 1017, UYO
Akwa Ibom State, Nigeria

The words "nuclear technology" registers in many people's mind an atomic and a nuclear bomb hence nothing more than destruction. This impression is not always correct since nuclear technology is also used for peaceful purposes. Isotopes of some elements emit radiation as their nuclear decay and they are called radioactive isotopes, radioisotopes or radionuclides. Some of these radionuclides occur naturally while others are artificial and the study of these radionuclides is called nuclear science. Nuclear technology is therefore the various nuclear techniques developed from nuclear science which make use of mainly radioisotopes or radiation procedures in response to the challenges imposed by the nuclear age. Their range of application is extremely broad which may be both constructive and destructive.

The application of these nuclear techniques will therefore have some advantages and disadvantages on public health; since these radionuclides will be used in the environment. The inhabitants of the environment such as man, animals and plants may benefit from the detrimental effects of the nuclear accidents and radiations.

Advantages of Nuclear Technology

The socio-economic development of many great nations have been achieved through the help of nuclear technology. Some of the areas in which nuclear technology have been applied are power generation, medicine, industry, agriculture, research and environmental management.

The generation of electricity from nuclear power plants have now been practiced in many countries of the world. This source of energy has been recognised as an economic and a clean source of energy as compared to the other sources of energy. According to Atseyinlu (1992), the nuclear energy is a viable energy source, and is beneficial in many respects, but it involves great risks and environmental problems.

The determination of metabolic pathways, visualisation of organs, localisation of tumors, detection of abnormalities in diagnosis, use of radiation sources for therapy, sterilisation of medical instruments are some of the major goals of nuclear medicine. Nuclear medical equipment, including scintillation gamma chambers, High Energy Gamma (HEG) scanner and two channel profile scanners have been manufactured and are being used for detection of internal diseases. Wide use is made of radioisotope tracer techniques in this area, such as in the preparation of radiopharmaceuticals for clinical diagnosis of various abnormalities. In Nigeria, for example, where there are no definite nuclear programmes, some form of secondary applications of nuclear techniques in medicine have been done. These are found in areas of diagnosis or diseases prevalent in developing countries such as tuberculosis, viral hepatitis and malaria.

Nuclear techniques are used in the Industry in various ways. Some of these Include, the measure and control of fluid flow, wear and tear of engine parts, production of concrete polymer materials, optical glass colouring, plaster composition, hardening in large size electro technical products. Thermo-settling pipes, bands and other insulating and construction products have been produced with polyethylene which are treated with accelerated atomic particles. Radioisotope methods and equipment have been used in production of a non-stop analysis of the composition of substances for determining ash content of brown coal and coke and for measuring the depth of charge in blast furnaces; Radiation technologies have been used for leather conservation, rubber vulcanisation, textile fabrics, hardening of paints and varnishes, timber and abrasive materials and in disinfestation and conservation of works of art. In the beer industry, isotopic techniques are used in detecting the levels of beer in the bottles.

In agriculture, there are various uses of radioisotope tracers to monitor plant growth development and plant diseases. Radiation sources have been used to solve some agricultural problems — some of which include the elimination of insect pests by mass release of insects made sterile by irradiation, the radiation disinfestation of grain and the use of radiation to produce useful plant mutations. Nuclear techniques have been employed to preserve food and agricultural products. Radioisotopes have also been used as tracers in many research studies. In studies involving the rates of chemical reactions, structural determination mechanism of reactions and some physico-chemical properties of substances, radioisotopes and nuclear radiations are widely used.

Nuclear techniques are increasingly gaining grounds in environmental management. The use of isotopes and the development of analytical tools including tracer methods, Neutron Activation Analysis (NAA), X-ray fluorescence and atomic absorption spectrometry have added to the techniques available for the study and detection of environmental pollutants such as pesticides and toxic metals. The use of nuclear technique in ground water pollution research is an example of the value of nuclear techniques in water pollution studies. Sewage water purification is now done with radiation technologies and isotope techniques have greatly assisted in the studies of our ecosystem.

Health and Environmental Risks

Health and environmental risks are very vital issues when dealing with nuclear energy. Generation of nuclear energy as well as use of radioisotopes in research, medicine, agriculture, and industry produce radioactive wastes which add to the naturally occurring radioactive substances found in our environment. This addition of artificial radioactive substances causes concern, since they are more concentrated and contain substances of high level activity as well as substances of lower level activity but with very long life time. Studies show that the soil samples of Hiroshima bomb incident contains high levels of radioactivity up to date, (Sakanoue and Tsieji, 1971). If these substances are not properly handled, they can contaminate the environment and present serious health hazards to man, animals and plant lives. At present, studies have shown that most of our earth's surface is contaminated by radioactive fallouts (Essien, 1991).

The release of radioactive materials and radiations are the subsequent results of nuclear energy and most of the instances radioactivity released into the environment come from the misuse of nuclear energy by man as in nuclear weapon manufacturer, testing and use, and from improper handling methods and disposal of the radioactive materials. It is expected that careful handling, controlled and peaceful applications of nuclear technology will continue to have little or no serious adverse effect on the environment.

Nuclear Accidents and Nuclear Waste Disposal

All forms of engineering technology and mechanical machinery have some type of accident risk to their operators, owners and to the public at large. Nuclear technology and installations are no exception. There is always the great fear of nuclear radiation on the part of the public based on the memory of the effects of the nuclear weapons of the Second World War and the Nagasaki incident of 1945. Although the risk of a radioactive release accident is quite small, it is by no means negligible, and the fact that when one occurs, it can have horrifying consequences is what frightens people and generates opposition to development of nuclear energy (Aina. 1992). The SNAP - 9A incident and the recent Chernobyl nuclear disaster of 1986 have again showed that despite the elaborate safety measures in the nuclear industry, accidents could still occur. There is great need to constantly review the safety measures in the nuclear industry.

Management and disposal of radioactive waste is an important issue in the development of nuclear industry. This problem is viewed by the public as being so serious, and hence the agitation for the closure of the nuclear industry. The debate on the issue is very understandable as the public is confronted with the fact that some nuclear wastes release radioactivity of almost instant mortal level if no protection is provided and others maintain their radio toxic character over a period which are many times exceeding the history of man. It is worthy to mention here that the main objective of management and disposal of radioactive waste is control, containment and isolation from the biosphere so as to protect the environment and avoid health hazards. According to Aina, (1992), scientists and engineers meeting under the auspices of International Atomic Energy Agency (IAEA) have for a number of years held that no additional breakthrough in technology is needed for the safe disposal of any radioactive waste including high level such as spent fuel. Studies are continuing to further improve the already significant level of knowledge about long term behaviour of geologic repositories to facilitate selection of suitable locations.

Environmental Effects of Nuclear Waste

The application of nuclear sciences in industry, medicine, agriculture, research, environmental management and power generation produce radioactive waste which release radioactivity into the environment. These wastes may contain very high level of activities as well as low level activities. As discussed above, if the wastes are handled and disposed properly they pose negligible danger to the public but when improperly handled can lead to serious environmental hazards and loss of lives. The waste can lead to radioactive contamination of vegetable crops, vegetation grazing animals such as cows, sheep, horses and goats making them unfit for consumption. They can also contaminate our surface soils, water bodies, making our crops and marine foods also unfit for consumption. Groundwater may also be affected and the entire food chain connecting man to plant can be seriously affected. Generally, the radioactivity released could also have serious adverse effect on health man, such as cancer and could even lead to fatalities depending on the dose received.

The occurrence of a nuclear accident is another way nuclear technology might pose a significant danger to the public. The recent experience of Chernobyl accident in the USSR in 1986, led to environmental radioactive contamination of a very wide area. High levels of radioactivity were recorded in the air around the neighbouring countries. Apart from the fatalities in the immediate vicinity of the area, there were noticed contamination of food, water, milk and meat products which were declared unfit for consumption.

It is worth to note here that any form of nuclear radiation directly or indirectly produces ionisation and chemical change in its passage through matter. Therefore, intense irradiation of surface tissues are known to cause loss of hair and skin burns, blood producing cells in the spleen and bone marrow are particularly sensitive and there are high probability of contracting leukemia and cancer. Genetic mutation can be caused by radiation damage to the chromosomes and death can be caused by an acute over-exposure to radiation. Since damage or destruction to a cell requires a direct hit by only a single particle of radiation, it is wise to take precaution to avoid even the slightest exposure to any form of radiation from the nuclear waste.

Radiation Protection and Safety

There are very useful benefits derived from nuclear technology and we will continue to have workers in the nuclear industries, hence there is the need to establish radiation protections standards. The second international conference of radiology in 1928 established the International Commission on Radiation Protection (ICRP) to set the required standards of permissible exposure to radiation. A summary of these standards are presented in the table below for two categories of individuals namely (i)

Occupational, and (ii) the Ordinary Public.

In the S.I. Unit, the unit of radiation dose equivalent is the sievert (SV) which is defined as the dose in gray (GY) multiplies by the Quality Factor, (QF). Gray is defined as 1 joule per kilogram (1Kg) where 1Gy is equivalent to 100 rads. The rad is a quantitative measure of radiation energy absorption usually called the dose.

Organ/Body Tissue	Occupational Max. Permissible dose per year (mSv)	Ordinary Public Max. Permissible dose per year (mSv)
1. Gonads/Red bone marrow	50	7
2. Skin/Bone/Thyroid	300	30
3. Head/Forearms/ Feet/Ankles	750	75
4. Other Single organs	150	15

The commission recommended the following to be observed:

(i) The annual dose for occupational workers (those with routine exposure during their professional work) should not exceed 50mSv to the whole body.

(ii) Women of reproductive capacity should not receive more than 13 mSv on the abdomen for a quarter year.

(iii) Pregnant women should not receive more than 10 mSv throughout a quarter.

(iv) Radiation workers should avoid any unnecessary exposures.

We are all exposed to low level radiations every year. Studies have shown that an average American receives an average dose of about 1.3 mSv /year (Foster and Wright Jr. 1983).

Most of our low level radiations come from the following sources; cosmic radiations, ground radiation, internal sources, nuclear weapon testings, X-ray, medical checkups, wearing of luminous wristwatch, from watching coloured TV, nuclear power plants, etc. It is therefore very necessary that we stay away from any form of nuclear radiation as much as possible.

Conclusion

In conclusion, I seem to support the views of Awonaike (1992), who noted that there is no gain saying that application of nuclear technique would entail the consumption of radioactive food by the populace. We should know that we are all radioactive. There is no place on earth or in the universe, where one can hide from radiation. We all have some form of radioactive radium and carbon in our muscles and radioactive noble gases and tritium in our lungs. Studies have shown that radiation kills just as motor accidents and plane crash which are forms of engineering technology.

The potential benefits of nuclear technology for the development of our country can, therefore, not be over-emphasised, provided the safety requirements for the peaceful use of the nuclear technology are strictly observed. It is also viewed that the successful introduction of this technology requires interdisciplinary collaboration between relevant scientist, various government regulatory and financial agencies and industries. The health of the public will not be affected when all the arms associated with the operation, handling and supervision of the nuclear industry are all in place as in other developed countries.

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HOW BIG IS THE MOON AND HOW FAR IS THE SKY[1]?

D. S. Kothari
Department of Physics
University of Delhi, Delhi

It is a matter of common observation that the Sun, the Moon and constellations appear much bigger when near the horizon than when they are high up in the sky[1]. The Sun and the Moon when high up appear (to most people) a little less than a foot in diameter, and near the horizon they look from 2 to 3 times bigger – the effect is greater in twilight and when the sky is clouded. It is needless to add that the entire phenomenon is psychological for there is no physical reason why we should associate a linear size of one foot with an angle of about half a degree – the angle subtended by the Sun's diameter is 31' 59" and the mean angle[2] for the Moon's diameter is 31' 5', and why the size should appear to vary with altitude though the angle subtended at the eye and hence the size of the retinal image remains constant.

The apparent variation of size with altitude exists also in the after-image of the Sun (and also the Moon) which is obtained by viewing the Sun for an instant and then blanking. The after-image of the Sun at the horizon as background appears to be of the same size as the Sun, but is reduced to about half its size when projected on the sky near the zenith. If instead of projecting on the sky the after-image of the Sun when at horizon, we project it on a wall, then it appears smaller than the Sun if the distance of the wall is less than about 200 feet, but on a wall at about 200 feet or beyond the size appears to be the same as that of the Sun. This shows that the distance of the horizon-sky appears to be about 200 feet, and of the sky at zenith about half of this[3].

There seems to be a possible connection between the apparent variation of the size of heavenly bodies with the altitude and the apparent flattening of the vault of heaven.

A very interesting article by Professor H.N. Russell had appeared (Scientific American, Oct., 1940) on the subject of apparent variation in the size of the Moon. Also see Hargreaves, observatory, June, 1940.

[1]The apparent variation of size persists even when the bodies are seen through a telescope.

[2]When the Moon is at the horizon its distance from the observer is greater by the earth's radius than when it is at the observer's zenith, and therefore the angular diameter, at the horizon compared to that the at the zenith is actually smaller by 0.5′. The Variation in the distance of the Moon from the earth due to the eccentricity of its orbit introduces in the angular diameter a variation of over 10 per cent.

[3]200 feet is a little less than one-third the radius of stereoscopic vision calculated on the basis of one minute as the resolving power of the eye.

When we look at the sky, the impression that we get is not that of an inverted hemisphere with ourselves at its centre, but it appears like a flattened dome whose distance from eye to zenith is smaller than the distance from eye to horizon, the ratio being from 2 to 4 depending on the observer and the circumstances attending the observation. The apparent flattening of the sky is felt vividly when try to locate the mid-point of the arc joining the zenith and the horizon.

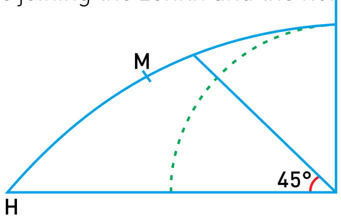


Fig.1. H is the horizon and Z is the zenith. M is the mid-point of the arc of the sky HZ.

If we point our hand or a stick in the direction of the mid-point, and if then the angle be measured, it is found that the altitude of the estimated mid-point M is much lower that 45°. It generally lies between 20° and 30° (Fig.1). In these and other psychological observations it is necessary that the observer should allow himself to get the impression as he sees or feels it, and not modify it by making a conscious effort in trying to see what he (according to his preconceived ideas or theoretical knowledge) ought to have seen. We are observing an illusion and the observation is vitiated to the extent that we make any conscious effort to overcome it. Scientific observation and study of illusion require psychological training.

Robert Smith[4] (Optics, 1738) suggested more than two centuries ago that we imagine the Moon, the Sun and the stars to be at the same distance as the sky, and therefore they appear to be several times more distant when at the horizon than at zenith: and as the angle subtended by than at the observer's eye remains the same, greater distance is associated with a proportionate increased (linear) size. In support of this view it may be noted that in twilight or when it cloudy the sky looks more flattened and therefore at the horizon farther away than ordinarily, and the Sun or the Moon at the horizon also appear larger. But why does the sky appear flattened? Let us first take up an interesting explanation due to Sterneck[5], which, however, as will appear later has to be discarded.

Sterneck gave an empirical relation between the true distance and the apparent distance of an object, and he was able to connect in this way a large number of phenomena, e.g., street-lamps father away than about 150 yards seem at night to be all at the same distance; rectangular fields seen from a train appear trapezia; the steepness of a mountain-slope is over-estimated when seen from the bottom of the mountain and under-estimated when we stand at the top; and the flattening of the celestial vault. Van Sternieck's formula is

$$x' = \frac{cx}{c+x} \qquad \text{...........} \ (1)$$

where x is the true distance, x' the apparent distance and c is a constant. The apparent distance is always smaller than the true

[4]M. Luckiesh, Visual Illusions, D. Van Nostrand Co., New York, (1922), Chapter XI.

[5]M. Minnaert, Light and Colour in the Open Air, Bell and Sons, London, (1940). Chapter IX. This is one of the best books on "everyday physics" that the writer has come across.

distance, and c is the limit which it approaches for increasing true distance. The value of c ranges from about 100 yards to 10 miles depending upon the nature of the object whose distance is estimated and on the circumstances under which it is observed.

When the sky is clouded, the clouds, being at an extremely small height compared to the earth's radius, form a practically flat ceiling above us[6]. The distance r between the observer and the cloud in the direction θ from the vertical is p sec θ, p being the vertical height of the cloud, and therefore if δ denotes the ratio of the apparent distance in the direction θ to the apparent vertical height of the cloud, then from equation (I), δ will be given by

$$d = \frac{1+\frac{c}{p}}{1+\frac{c}{p}\cos q} = \frac{d_0}{1+(d_0-1)\cos q} \qquad \text{......... 2}$$

where δ_0 is the ratio of the apparent horizon-distance to zenith-distance. The cloudy sky should therefore appear like a hyperboloid of revolution (with the observer at its focus), which does agree with our general impression of it.

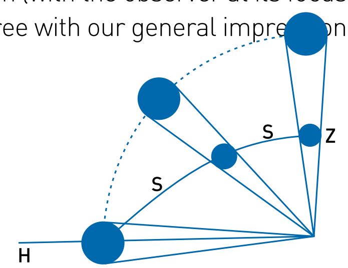


Fig. 2. H is the horizon, Z is the zenith, S.S. represents the sky. The figure illustrates Robert Smith's explanation of the apparent variation in the size of the Sun (or the Moon) due to the apparent flattening of the sky.

However, not only a cloudy sky, but a blue and a starry sky also give the same impression of being flattened – only the flattening is less, and it is difficult to see how Van Sterneck's explanation could be applied to a featureless blue sky. But a serious objection to this explanation is the fact that the apparent shape of the sky is dependent on the way the observer holds his body during the observation. If instead of standing, the observer lies flat on is back on the ground, the appearance of the sky is completely altered –.it is spherical towards his feet but compressed towards his head. The flattening of the sky is relative to the observer's "personal horizon" which is a great circle perpendicular to his backbone. When the head is held in its normal position relative to the body, the observer's gaze is towards his personal horizon. The head has to be thrown backwards to see the sky above the personal horizon, and bent forward to see below it. The sky below the personal horizon appears spherical and flattended above it. In fact, if an observer supports himself from a horizontal bar with the body vertical and head downwards, the whole sky is below his personal horizon an appears to him spherical[7].

[6] If the cloud be at vertical height of one mile, then, even for an altitude of 100, the distance of the cloud, assuming the cloud-bank to be a flat ceiling, will exceed the distance calculated on the assumption that the cloud-bank is a concentric sphere round the earth by less than 0.5 per cent.

[7] M. Minnaert, loc, cit., p.163 Fig 3 is also taken from this book.

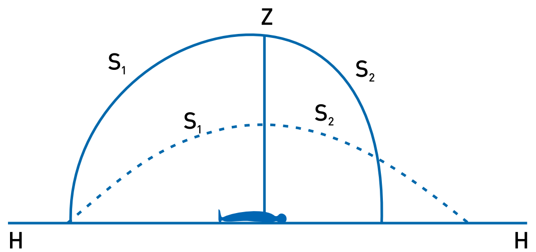


Fig. 3: H is the horizon and Z is the zenith. S_1 S_1 is the apparent shape of the sky when the observer is standing. S_2 S_2 is the apparent shape of the sky when the observer is lying on his back.

It is not only the flattening of the sky which is related to the personal horizon, but the apparent variation in the size of heavenly bodies is also dependent on it. This has been conclusively established by Professor Boring[8] (and his colleagues) at Harvard, who recently reported his results to the United States National Academy of Sciences. The Moon looks big when it is near the observer's personal horizon. It appears smaller when it is away form the personal horizon, it being immaterial whether it is above or below it – the phenomenon is symmetrical with respect to the personal horizon. Further, the Harvard psychologists find that the Moon, even when high in the sky, reduces the impression of looking (to an observer standing on the ground) as big as a disk about 5 inches in diameter placed 10 or 12 feet away – the apparent angular diameter is about four times its real value. At the horizon the Moon appears twice a big. The apparent magnification of the angular diameter is significant: our estimates of the size and distance are not conditioned by the actual visual angle.

The question remains: why the Moon looks largest when it is at the personal horizon? Why there is an association between the apparent size of the Moon and the bending of the head (backwards of forwards depending on whether the Moon is above or below the personal horizon) necessary to look at it? A possible explanation[9] is to be sought in our everyday experience. When an object approaches us we have in most circumstances to bend our head to see it, – forwards if the object is on the ground, and backwards if it is a flying bird or a cloud. The angle subtended by the object increases with increasing bending of the head, but, provided the object was approaching us from not too large a distance, our training in interpreting visual perceptions has been such that the impression of its size remains almost the same: it is nearly its true size. It seems that we assign unvarying size not by making allowance for the varying distance, but on the contrary we carry as it were the 'size' in us (' we are geometricians by nature') and judge of distance from the visual angle through its (size) help. We get so much accustomed from common experience to a large visual angle when the object is seen with the head in its normal position and to a small visual angle when the same object is seen with a bent head – the impression of size being the same in the two cases –that for the Moon, as the angle

[8] H.N. Russell, loc. Cit.

[9] This has been suggested by Professor Ruessell; loc.cit. See also Minnaert, p. 162.

[10] It seems that a forward bending of the head has no effect on our estimate of distance, but bending the head backwards produces a bias in favour of underestimating the distance. The value of c in Sterneck's formula is unaffected in the former case, but reduced in the latter case.

remains the same, we get an impression of a smaller size when we have to bend our head in order to see it.

The apparent shape of the sky can also be explained on similar lines by assuming that our daily experience accustoms us to a relation between distance of objects and the bending of the head necessary to see them, but it must be admitted that these are only plausible suggestions and at present no explanation of the apparent variation in the size of heavenly bodies or the shape of the sky can be regarded as reasonably satisfactorily established[10].

We have mentioned that if the distance of an object is not too large, the impression of its size is independent of the distance. When the distance is large, the apparent size decreases, and it appears very likely that the relation between apparent size and real size is of the same form as Sterneck's formula for apparent dis

$$y' = \frac{yc'}{c'+x}$$

or

$$y = y' + \frac{y'}{c'}x \qquad (3)$$

where y' is the apparent size of an objet of true size y and at a distance x,c' is a constant, its particular value depending on the circumstances under which the object is observed and is probably different from value in the distance-formula (1). The apparent size is half the true size for x = c' . So long as x is small compared to c, the apparent size does not vary appreciably, it is almost the same as the true size. For x large compared to c', the apparent size is inversely proportional to x. Two straight lines (telegraph wires, long stretched strings, straight edges of a foot-path etc.) will appear when they are not actually parallel, but the distance between them increases linearly with x so as to satisfy (3). Relation (3) should hold fairly accurately for terrestrial objects.

When we look at an object through a telescope or binoculars, the visual angle subtended at the eye is increased by a factor which is the magnifying power (m) of the instrument. The effect is the same as if the true distance of the object had been reduced m times, and the apparent size of the object as seen through the telescope will be

$$y' = \frac{yc'}{c' + x/m} = \frac{myc'}{mc' + x} \qquad \text{.........(4)}$$

For x small compared to c' m, the apparent size will be almost the same as the true size. This seems to agree with our (qualitative) experience and a detailed investigation will be interesting.

It may be remarked that our judgement of speed say, when we are sitting in a car, is also modified because of the under-estimation of distance. If we judge the speed by looking at an object at a distance x from us, then the true speed $\left(\frac{dx}{dt}\right)$ and the apparent speed $\left(\frac{dx'}{dt}\right)$ are connected by

The article written by late Prof. D. S. Kothari was published in Science and Culture in 1941. Professor Kothari was teaching Physics in the University of Delhi at that time. Prof.Kothari played a significant role in the development of science and technology in post-Independence era. He acted as Scientific Advisor to the Government of India, Vice Chairman, UGC and as Chancellor of the Jawaharlal University.

the relation $\left(\frac{dx'}{dt}\right) = \left(\frac{c}{c+x}\right)^2 \frac{dx}{dt}$, and if we are looking through binoculars, it becomes $\frac{dx'}{dt} = \frac{1}{m}\left(\frac{mc}{mc+x}\right)^2 \frac{dx}{dt}$ or for x small compared to mc, the apparent speed is l/mth of the true speed.

ASTRONOMY IN SCIENCE AND IN HUMAN CULTURE

JAWAHARLAL NEHRU MEMORIAL LECTURE 1969

S. Chandrasekhar
Distinguished Service Professor of Astrophysics
University of Chicago

It is hardly necessary for me to say how deeply sensitive, I am to the honour of giving this second lecture in this series founded in the memory of the most illustrious name of independent modern India. As Pandit Jawarharlal Nehru has written, "The roots of an Indian grow deep into the ancient soil; and though the future beckons, the past holds back."

I hope I will be forgiven if I stray for a moment from the announced topic of my lecture to recall, how forty-one years ago, I was one of thousands of students who went to greet young Jawaharlal (as we used to call him at that time) on his arrival to address the National Congress meeting in Madras that year.

I recall also how the dominant feeling in all of us at that time was one of intense pride in the men amongst us and in what they inspired in us. Lokamanya Tilak, Mahatma Gandhi, Lala Lajpat Rai, Motilal Nehru, Jawaharlal Nehru, Sardar Patel, Sarojini Naidu, Rabindranath Tagore, Srinivasa Ramanujan—names that herald the giants that lived amongst us in that pre-dawn era.

The topic I have chosen for this lecture, "Astronomy in Science and in Human Culture," is so large that I am afraid that what I can say on this occasion can at best be a collection of incoherent thoughts. In the first part of the lecture I shall make some general observations on ancient Hindu astronomy, particularly with reference to the way it relates Hindu culture to the other cultures of antiquity. I am not in any sense a student of these matters. My knowledge is solely derived from the writings of a distinguished historian of science, Professor Otto Neugebauer, who has kindly helped me in preparing this part of my lecture.

In the second part of the lecture I shall say something about the particular role of astronomy in expanding the realm of man's curiosity about his environment.

One aspect of astronomy is certain: it is the only science for which we have a continuous record from ancient times to the present. As Abdul-Qasim Said ibn Ahmad wrote in 1068 in a book entitled, "The Categories of Nations": "The category of nations which has cultivated the sciences form an elite and as essential part of the creation of Allah." And he enumerated eight nations as belonging to this class: "The Hindus, the Persians, the Chaldeans, the Hebrews, the Greeks, the Romans, the Egyptians and the Arabs".

Chronologically, the interactions between the leading civilisations of the ancient world are far more complex than this simple enumeration suggests. And a study of these interactions provides us with the most impressive testimony to man's abiding interest in the universe around him.

We know today that Babylonian astronomy reached a scientific level only a century or two before the beginning of Greek astronomy in the fourth century B.C. The development of Hellenistic astronomy, after its early beginnings, to its last perfection by Ptolemy in 140 A.D. is largely unknown. Then about three centuries later Indian astronomy, manifestly influenced by Greek methods, emerged. This last fact raises the question as to the way in which this transmission of information from Greece to India took place. Its answer is made particularly difficult since it implies possible Persian intermediaries. Some centuries later, in the ninth century, Islamic astronomy appears influenced by Hindu as well as Hellenistic sources.

While the Greek astronomy rapidly became dominant in the eastern part of the Muslim world from Egypt to Persia, the methods of Hindu astronomy persisted in Western Europe even as
late as the fifteenth century, as I shall indicate later.

As far as Babylonian astronomy is concerned, we know very little about its earlier phases. But it appears that a mathematical approach to the prediction of lunar and planetary theory was not developed before the fifth century B.C. that is to say barely prior to the corresponding stage of development of Greek astronomy. It is, however, generally agreed that the development of Babylonian astronomy took place independently of the Greeks.

An important distinction between the Babylonian and the Greek methods is this: Babylonian methods are strictly arithmetical in character and are not derived from a geometrical model of planetary motion; the Greek methods, on the other hand, have invariably had a geometric basis. This distinction enables us to identify their influence in Hindu astronomy.

Let me make a few remarks on Greek astronomy as it is relevant to my further discussion.

The earliest Greek model that was devised to account for the appearance of planetary motion is that of Eudoxus in the middle of fourth century B.C. On this model planetary motion was interpreted as a superposition of uniform rotations about certain inclined axes. In spite of many glaring inadequacies, this model had a profound impact on subsequent planetary theory. The culmination of Hellenistic astronomy is, of course, contained in Ptolemy's "Almagest" –perhaps the greatest book on astronomy ever written; and it remained unsurpassed and unsuperceded until the beginning of the modern age of astronomy with Kepler.

Ptolemy's modification of lunar theory is of special importance for the problem of the transmission of Greek astronomy to India. The essentially Greek origin of the Surya Siddhanta which is the classical textbook of Hindu astronomy, cannot be doubted: it is manifested in the terminology, in the units used, and in the computational methods. But Hindu astronomy of the North does not appear to have been influenced by the Ptolemic refinements of the lunar theory; and this appears to be true with planetary theory also. This fact is of importance: a study of Hindu astronomy will give us much needed information on the development of Greek astronomy from Hipparchus in 150 B.C. to Ptolemy in 150 A.D.

In early Hindu astronomy, as summarized by Varaha Mihira in the Pancha Siddhantika, we can distinguish two distinct methods of approach: the trigonometric methods best known through Surya Siddhanta and the arithmetical methods of Babylonian astronomy in the astronomy of the South. The Babylonian influence has come to light only in recent years; and I shall presently refer to its continued active presence in the Tamil tradition of the seventeenth and the eighteenth centuries.

I should perhaps state explicitly here that the fact that Hindu astronomy was deeply influenced by the West does not by any means exclude that it developed independent and original methods. It is known, for example, that in Hindu astronomy the chords of a circle were replaced by the more convenient trigonometric function Sin a—(R sin a).

Before I conclude with some remarks on the simultaneous existence of two distinct astronomical traditions in India I should like to illustrate my general remarks by two specific illustrations which are of some interest.

In 1825 Colonel John Warren, of the East India Company, stationed at Fort St. George, Madras, wrote a book of over 500 quarto pages entitled Kala Sankalita with a Collection of Memoirs on the Various Methods According to Which the Southern Part of India divided Time. In this book, Warren described how he had found a calendar maker in Pondicherry who showed him how to compute a lunar eclipse by means of shells placed on the ground and from tables memorized as he stated "by means of certain artificial words and phrases." Warren narrates that even though his informer did not understand a word of the theories of Hindu astronomy he was nevertheless endowed with a memory sufficient to arrange very distinctly his operations in his mind and on the ground." And Warren's informer illustrated his methods by computing for him the circumstances of the lunar eclipse of May 31–June 1, 1825 with an error of + 4 minutes for the beginning, –23 minutes for the middle, and – 52 minutes for the end. But is it not the degree of accuracy of his result that concerns us here; it is rather the fact that a continuous tradition still survived in 1825, a tradition that can be traced back to the sixth century A.D. with Varaha Mihira, to the third century in the Roman Empire and to the Seleucid cuneiform tablets of the second and the third centuries.

A second instance I should like to mention is an example of the survival of Hindu astronomy in parts of the Western world that were remote from Hellenistic influences during the medieval times. A Latin manuscript has recently been published which contains chronological and astronomical computations for year 1428 for the geographical latitude of Newminster, England. It used methods manifestly related to Surya Siddhanta. Obviously one has to assume Islamic intermediaries for a contact of this kind between England of the fifteenth century and Hindu astronomy.

While Surya Siddhanta manifests Greek

influence, Babylonian influence has recently been established in the post-Vedic and pre-Surya Siddhanta period. For example, in the astronomy of that period, the assumption of a longest day of 18 muhurtas and a shortest day of 12 muhurtas were made. This ratio of 3:2 is hardly possible for India. But it is appropriate for Mesapotamia; and possible doubts about the Babylonian origin of this ratio were removed when the same ratio was actually found in Babylonian texts. In addition, a whole group of other parallels between Babylonian and Indian astronomy have since been established. Thus, the most characteristic feature of Hindu time reckoning—the tithis—occurs in Babylonian lunar theory.

Clearly all these facts must be taken into account in any rational attempt to evaluate the intellectual contacts between ancient India and the Western world. This problem of the foreign contacts is by no means the only, or even the most important, fact that is to be ascertained. One must consider the Dravidic civilisations of the South on par with the history, the language, and the literature of the Aryan component of Indian culture. It is, as Neugebauer has emphasised, this dualism of Tamil and Sanskrit sources that will provide for us, eventually, a deeper insight into the structure of Indian astronomy.

In his book "Rome Beyond Imperial Frontiers". Sir Mortimer Wheeler comes to the conclusion that "the far more extensive contacts with South India have been a blessing to the archeologists" but he adds that "these contacts had no influence on these cultures themselves." Hindu astronomy provides an example to the contrary. Exactly as it is possible to distinguish between commercial contacts which India had through the Punjab or through the Malabar and Coromandal Coast, it is possible to distinguish the astronomy of the Surya Siddhanta on the one hand and the Tamil methods on the other. This distinction is indeed very marked. The Surya Siddhanta is clearly based on pre-Ptolemaic Greek methods while the Tamil methods, in their essentially arithmetical character, manifest the influence of Babylonian astronomy of the Selecuid-Parthian period.

One must not, of course, conclude that the Tamil methods were imported directly from Mesapotamia while the geometric methods came to the North via the Greeks and through, Persian intermediaries. And as I stated earlier, the fact that the Surya Siddhanta appears to have not been influenced by the Ptolemaic refinements, provides an important key to the development of Hellenistic astronomy between the times of Hipparchus and Ptolemy.

A proper assessment of the role of Hindu science in the ancient world has yet to be made. The problem is made more difficult, than is necessary, by the tendency of the majority of publications of Indian scholars to claim priority for Hindu discoveries and to deny foreign influence, as well as the opposite tendency among some European scholars. These tendencies on both sides have been aggravated by the inadequate publication of the original documents: this is indeed the most pressing need. Since no astronomy at an advanced level can exist without actual computations of planetary and lunar ephimerides, it must be the first task of the historian of Hindu astronomy to search for such texts. Such texts are indeed preserved in great numbers, though actually written in very late periods. But the publication of this material is an urgent need in the exploration of oriental astronomy.

Let me conclude this somewhat incoherent account, bearing on the ancient culture of India, by emphasising that its principal interest lies not in the sharing or in the apportioning of credit to one nation or another but rather in the continuing thread of common understanding that has bound
the elite nations of Abul-Qasim ibn Ahmad in man's constant quest to comprehend his environment.

The pursuit of astronomy at the more sophisticated level of modern science, since the time of Galileo and Kepler, is concerned with the same broad questions even though that fact is often observed by the technical details of particular investigations.

Questions that may naturally occur to one often appear to be meaningless in the context of current science. But with the progress of science questions that appear as meaningless to one generation become meaningful to another. It is to
this aspect of the development of astronomy in recent times that I should like to turn my attention now.

The first question that I shall consider concerns the assumption that is implicit in all sciences. Nature is governed by the same set of laws at all places and at all times, i.e. Nature's laws are universal. That the validity of this assumption must be raised and answered in the affirmative was the supreme inspiration which came to Newton as he saw the apple fall. Let me explain.

Galileo had formulated the elementary laws of mechanics governing the motions of bodies as they occur on the earth; and the laws he formulated were based on his studies of the motions of projectiles, of falling bodies, and of pendulums. And Galileo had, of course, confirmed the Copernican doctrine by observing the motions of the satellites of Jupiter with his telescope. But the question whether a set of laws could be formulated which governed equally the motions of all bodies, whether they be of stones thrown on the earth or of planets in their motions about the sun, did not occur to Galileo or his contemporaries. And it was the falling apple that triggered in Newton's mind the following crucial train of thought.

All over the earth objects are attracted towards the center of the earth. How far does this tendency go? Can it reach as far as the moon? Galileo had already shown that a state of uniform motion is as natural as a state of rest and that deviations from uniform motion must imply force. If then the moon were relieved of all forces, it would leave its circular orbit about the earth and go off along the instantaneous tangent to the orbit. Consequently, so argued Newton, if the motion of the moon is due to the attraction of the earth, then what the attraction really does is to draw the motion out of the tangent and into the orbit. As Newton knew the period and the distance of the moon, he could compute how much the moon falls away from the tangent in one second. Comparing this result with the speed of falling bodies, Newton found the ratio of the two speeds to be about 1 to 3600. And as the moon is sixty times farther from the center of the earth than we are, Newton concluded that the attractive force due to the earth decreases as the square of the distance. The question then arose: If the earth can be the centre of such an attractive force, then does a similar force reside in the sun, and is that force in turn responsible for the motions of the planets about the Sun? Newton immediately saw that if one supposed that the Sun had an attractive property similar to the earth, then Kepler's laws of planetary motion become explicable at once. On these grounds, Newton formulated his law of gravitation with lofty grandeur. He stated: "Every particle in the universe attracts every other particle in the universe with a force directly as the product of the masses of the two particles and inversely as the square of their distance apart." Notice that Newton was not content in saying that the Sun attracts the planets according to his law and that the earth also attracts the particles in its neighbourhood in a similar manner. Instead with sweeping generality, he asserted that the property of gravitational attraction must be shared by all matter and that his law has universal validity.

During the eighteenth century, the ramifications of Newton's laws for all manner of details of planetary motions were investigated and explored. But whether the validity of Newton's laws could be extended beyond the solar system was considered doubtful by many. However, in 1803, William Herschel was able to announce from his study of close pairs of stars that in some instances the pairs represented real physical binaries revolving in orbits about each other. Herschel's observations further established that the apparent orbits were ellipses and that Kepler's second law of planetary motion, that equal areas are described in equal times, was also valid. The applicability of Newton's laws of gravitation to the distant starts was thus established. The question whether a uniform set of laws could be formulated for all matter in the universe became at last an established tenet of science. And the first great revolution in scientific thought had been accomplished.

Let me turn next to the second great revolution in
explicit context of astronomy that was accomplished during the middle of the last century.

During the eighteenth century the idealist philosopher Bishop Berkeley claimed that the sun, the moon, and the stars are but so many sensations in our mind and that it would be meaningless to inquire, for example, as to the composition of the stars. And it was an oft-quoted statement of Auguste Compte, a positivist philosopher, influential during the early part of the nineteenth century, that is in the nature of things that we shall never know what the stars are made of. And yet that very question became meaningful and the center of astronomical interest very soon afterwards. Let me tell this story very briefly.

You are familiar with Newton's demonstration of the chapter of white light by allowing sunlight to pass through a small round hole and letting the pencil of light so isolated fall on the face of a prism. The pencil of light was dispersed by the prism into its constituent rainbow colours. In 1802 it occurred to an English physicist, William Wollaston, to substitute the round hole, used by Newton and his successors to admit the light to be examined with the prism, with an elongated crevice (or slit as we would now say) 1/20th of an inch in width. Wollaston noticed that the spectrum thus formed, of light "purified" (as he stated) by the abolition of over-lapping images, was traversed by seven dark lines. These Wollaston took to be the natural boundaries of the various colours. Satisfied with this quasi-explanation, he allowed the subject to drop. The subject was independently taken up in 1814 by the great Munich optician Fraunhofer. In the course of experiments of light, directed towards the perfecting of his achromatic lenses, Fraunhofer, by means of a slit and a telescope, made the surprising discovery that the solar spectrum is crossed not by seven lines but by thousands of obscure streaks. He counted some six hundred and carefully mapped over three hundred of them. Nor did Fraunhofer stop there. He applied the same system of examination to other stars; and he found that the spectra of these stars, while they differ in details from that of the Sun, are similar to it in that they are also traversed by dark lines.

The explanation of these dark lines of Fraunhofer was sought widely and earnestly. But convincing evidence as to their true nature came only in the fall of 1859 when the great German physicist Kirchhoff formulated his laws of radiation. His laws in this context consist of two parts. The first part states that each substance emits radiations characteristic of itself and only of itself. And the second part states that if radiation from a higher temperature traverses a gas at a lower temperature, glowing with its own characteristic radiations, then in the light which is transmitted the characteristic radiations of the glowing gas will appear as dark lines in a bright background. It is clear that in these two propositions we have the basis for a chemical analysis of the atmospheres of the Sun and the stars. By comparisons with the spectral emissions produced by terrestrial substances, Kirchhoff was able to identify the presence of sodium, iron, magnesium, calcium, and a host of other elements in the atmosphere of the Sun. The question which had been considered as meaningless only a few years earlier had acquired meaning. The modern age of astrophysics began with Kirchhoff and continues to the present. And we all know that one of the major contributions to our understanding of the spectra of stars and the physics of stellar atmospheres was made in our own times by Meghnad Saha.

Now I come to a question that man has always put to Nature: Was there a natural beginning to the universe around us? Or to put the question more directly: How did it all begin? All religions and all philosophical systems have felt the need and the urge to answer this question. Indeed, one may say that a theory of the universe, a theory of cosmology, underlies all religions and all myths. And one of the earliest cosmologies, formulated as such, occurs in the Babylonian epic Enuma Elish in the second millenium B.C. The poem opens with a description of the universe as it was in the beginning:

When a sky above had not been mentioned
And the name of firm ground below had
not been thought of

When only primeval Apsu, their begetter,
And Mummu and Ti'amat-she who gave birth to
them all-

Were mingling their waters in one;

When no God whosoever had appeared,
Had been named by name had been determined as to his lot,

Then were Gods formed within them.

Whether the question of the origin of the universe can be answered on rational scientific grounds is not clear. It might be simplest to suppose that in all aspects the astronomical universe has always been. Or, alternatively, following Compte we might even say that it is in the nature of things that we shall never know how or when the universe began. Nevertheless, recent discoveries in astronomy have enabled us for the first time to contemplate rationally the question: Was there a natural beginning to the present order of the astronomical universe? A related question is: If the astronomical universe did have a beginning, then are we entitled to suppose that the laws of Nature have remained unchanged? The two questions are clearly related.

Let me take the second question first. Have the laws of Nature remained the same? Can the universality of Nature's laws implied by Newton in his formulation of the laws of gravitation, be extended to all time in a changing universe?

It is clear that over limited periods of time the laws of Nature can be assumed not to have changed. After all, the motions of planets have been followed accurately over the past three centuries—and less accurately over all historical times–and all we know about planetary motions has been accounted for with great precision with the same Newtonian laws and with the same value for the constant of gravitation. Moreover, the physical properties of the Milky Way system have been studied over most of its extent–and its extent is 30,000 light years. It can be asserted that the laws of atomic physics have not changed measurably during a period of this extent. And on the earth geological strata have been dated for times which go back several hundreds of millions of years. In particular the dating of these strata by the radio-active content of the minerals they contain assumes that the laws of physics have not changed over these long periods. But if during these times the astronomical universe in its broad aspects has not changed appreciably then the assumption that the laws have not changed appreciably during these same periods would appear to be a natural one. The questions that I have formulated, to have meaning, must be predicted on the supposition that there is a time scale on which the universe is changing its aspect. And if such a time scale exists, the first question is: What is it?

That a time scale characteristic of the universe at large exists was first suggested by the discoveries of Hubble in the early twenties. There are two parts to Hubble's discoveries. The first part related to what may be considered as the fundamental unit or constituents of the universe. It emerged unequivocally from Hubble's studies that the fundamental units are the galaxies of which our own Milky Way system is not an untypical one. Galaxies occur in a wide variety of shapes and forms. The majority exhibit extraordinary organization and pattern.

To fix ideas, let me say that a galaxy contains some ten billion or more stars; its dimension can be measured in thousands of light years: our own galaxy has a radius of 30,000 light years. Further the distance between galaxies is about

50 to 100 times their dimensions.

The second part to Hubble's discovery is that beyond the immediate neighbourhood of our own Milky Way system, the galaxies appear to be receding from us with a velocity increasing linearly with the distance. In other words, all the galaxies appear to be running away from us as though, as Eddington once said, "we were the plague spot of the universe". Hubble's law that galaxies recede from us with a velocity proportional to the distance was deduced from an examination of their spectra.

Now suppose that we take Hubble's law literally. Then it follows that a galaxy which is twice as far as another will be receding with a velocity twice that of the nearer one. Accordingly, if we could extrapolate backwards, then both galaxies would have been on top of us at a past epoch. More generally, we may conclude that if Hubble's relation is a strict mathematical one, then all the galaxies constituting the astronomical universe should have been together at a common point at a past calculable epoch. Whether or not we are willing to extrapolate Hubble's law backward in this literal fashion, it is clear that the past epoch calculated in the manner I have indicated does provide a scale of time in which the universe must have changed substantially. Current analysis of the observations suggests that the scale of time
so deduced is about seventy thousand million years.

With the time scale established, the question I stated earlier can be rephrased as follows: Have the laws of Nature been constant over periods as long as say thirty or forty billion years? And, what indeed was the universe like seventy thousand million years ago? These questions cannot be answered without some underlying theory. While there are several competing theories that are presently being considered, I shall base my remarks on the framework provided by Einstein's general theory of relativity. This theory appears to me the most reasonable.

This is clearly not the occasion to digress at this point and describe the content of the theory of relativity. Suffice it to say that it is a natural generalisation of Newton's theory and a more comprehensive one. On Einstein's theory, applied to the astronomical universe in the large, it follows that at each instant the universe can be described by a scale of distance which we may call the radius of the universe. At a given epoch, it measures the farthest distances from which a light signal can reach us. This radius varies with the time. Its currently estimated value is ten thousand million light years. But the most important consequence that follows from the theory is that this radius of the universe was zero at a certain calculable past epoch some seventy thousand million years ago. In other words, the conclusion arrived at by a naive extrapolation backwards of Hubble's law, interpreted literally, is indeed a valid one. That the theory predicts such a singular origin for the universe is surprising; but it has been established rigorously, with great generality, by a young English mathematician, Roger Penroes.

And finally, it is an exact consequence of the theory that the ratio of the wavelengths of an identified line in the light of a distant galaxy to the wavelength of the same source as measured here and now is the same as the ratio of the radius of the universe now and as it was when the light was emitted by the galaxy.

During the past few years, a dozen or more objects have been discovered for which the ratio of the wavelengths I mentioned is about three. Precisely what has been found is the following. In a laboratory source hydrogen emits a line with a wavelength that is about a third of the wavelength of the visible extreme violet light. But this same line emitted by the stellar object in the remote past and arriving here on earth now is actually observed in visible light. The fact that all the identifiable spectral lines in these objects are shifted by a factor of about three, means that the radius of the universe at the time light left these objects was three times smaller and the density was some twenty-seven times greater than they are now. And a careful analysis of the spectrum shows that during this span of time at any rate the laws of atomic physics have not changed to any measurable extent. To have been able to see back in time when the density of the universe was thirty times what it is now is, of course, a considerable advance. But even this ratio is very far from what it would have been if we take the relativistic picture and go further back in time when the radius of the universe was say ten thousand million times smaller, not merely three times or a thousand times smaller. Does it appear that this extrapolation is meaningless and fanciful? But the general theory of relativity gives a theoretical meaning to such a question since a state of affairs attained by such extrapolation is predicted as an initial state for our present universe. In other words, the question is meaningful, and one can reasonably ask: Is there anything we can observe now that can be considered as the residue or the remnant of that initial singular past? But to answer this question we must take the relativistic picture seriously and determine what it has to say about that remote past. Such a determination has been made by Robert Dicke and his associates at Princeton.

Dicke calculated that at the time the radius of the universe was 10^{10} times smaller, the temperature should have been some ten thousand million degrees—in other words a veritable fireball. And as the universe expanded, radiation of this very high temperature, which would have filled the universe at that time, would be reduced. For example, its temperature would have fallen to ten thousand degrees after the first ten million years. As the universe continues to expand beyond this point, the radiation will cool adiabatically, i.e., in the same manner as gas in a chamber will cool if it is suddenly expanded. And Dicke concludes that the radiation from the original fireball must now fill the universe uniformly, but that its temperature must be very low—in fact 3^0 Kelvin, a temperature that is attainable in the laboratory only by liquefying helium. It corresponds to radiation at a temperature of 270^0 of frost. How can we detect this low temperature radiation?

It can be shown that this radiation at 270^0 of frost should have its maximum observable intensity at wavelength in the neighbourhood of

3 millimeters i.e., the radiation must be present in the microwave region. The remarkable fact is that radiation in these wavelengths has been detected; it comes with incredible uniformity from all directions; and they have all the properties that
one might, on theoretical grounds, want to attribute to such fossil radiation from the original fireball.

With these discoveries I have described astronomy appears to have justified the curiosity that man has felt about the origin of the universe, from the beginning of time.

As I said at the outset, man's contemplation of the astronomical universe has provided us with the one continuous thread that connects us with antiquity. And might I add now that it has also inspired in him the best.

WHAT IS THE UNIVERSE LIKE?

J.V. Narlikar

Based on the lecture by Professor J.V. Narlikar, delivered at the National Science Exhibition for Children, 1976, sponsored by the Jawaharlal Nehru Memorial Fund and NCERT. We express our thanks to the Jawaharlal Nehru Memorial Fund for sponsoring the lecture.

Fig 1. Photograph of the 200 inch telescope at Mt. Palomer, southern California, operated by the Hale observatories. (Photograph : Hale observatories)

I have chosen the title "What is the universe like?"
I should have added a few more words to it and said "What is the universe like to an astronomer or to an astrophysicist?" because the universe by itself means everything and it would mean a different thing to different people. So it will not be possible for anyone to do justice with the title as it stands and, therefore, I would like to say right in the beginning that I want to give you an astronomer's view of the universe: which is the large scale structure of the universe.

Now, if you look at the night sky you see stars, the planets and the moon; but you should also be aware of the fact that there is a lot in the space which your eyes cannot see. It is because the human eyes have limitations imposed by their biological construction. Man is aware of these limitations and has invented the telescope and various other types of apparatus which help him to observe the universe.

In the first slide (Fig. 1) I will show you one such apparatus—the telescope. In this case this is the biggest optical telescope in working condition. If you are thinking of a telescope as something which you put to your eye and look through, that is not the case here. In fact, instead of attaching the telescope to the eyes of human beings, the human beings can in fact get inside the telescope and look through. Instruments of various sophisticated types such as photographic plates, image tubes and the like are used to collect information as it comes through the telescope. Now I would like to take you on a short trip round the universe. I will like to describe you what the universe looks like through some slides.

I have, by the way, dropped the moon because I will come to it later in a different context. This is the planet Mars (Plate I, Fig. 2)—if we are going away from the sun the first planet that we will encounter. Let me say something about its distance from here. We take distance from our sun as a unit, which is called in technical terms the astronomical units that is about 150 million kilometers. That is the distance and you can work it out (if you know the speed of light) that it takes about 8 minutes for light to come from the sun to us (earth). Now, compared to this astronomical unit, Mars is 1.6 astronomical units from the sun.

The Planet Jupiter (Plate I, Fig. 3) which is further away. It is about 5.2 astronomical units, i.e., more than five times further away from the sun than the earth is. Then we go to a more remote planet which is about ten astronomical units away from the sun. Now one could go on in this fashion and I could tell you that the furthest well-established planet in our solar system at present is Pluto which is about 39.5 astronomical units or nearly 40 times further away from the sun than our earth is. So let us leave the solar system and go a bit further out, and see what we have in our OWN GALAXY which is a multitude of stars. But before that let me mention COMETS which come and go from close to the sun and disappear and can be very far away—almost well beyond the remotest planet and then come again. Their orbits are different from the orbits of planets. The Halley's Comet which comes every 75-76 years is expected again around 1986. As we leave the solar system we encounter vast collections of stars, gas and dust which form what is known as NEBULAE. A nebula is a bright object and there are many such nebulae in the MILKY WAY system in our galaxy.

In the next slide is shown a very interesting object. It is called the CRABNEBULA (Plate II, Fig. 4) and it contains a lot of information of different types for the astronomers; it was first seen, according to the ancient records available, by the Chinese and Japanese astronomers in the form of very bright stars even during the day time. You can imagine how bright it must have been. But it did not last like that for very long; it lasted probably a day or two and then it disappeared, which means, it became very faint and now you cannot see it with naked eyes. But when you take a picture you see something like this which appears to have a lot of filaments and there is an evidence of an explosion at the centre of this object. Now what does it mean? It means that there was an exploding star, a star which was seen to explode in the year 1054 on the 4th of July, according to the records. Now, this is known as a remnant of a SUPERNOVA. A supernova is an exploding star. A star explodes when its interior gets too hot and it becomes unstable and it blows off its envelope, that is, its outer region. This seems to have occurred 900 year ago. One can ask the question why it was not seen in India. Certainly we do not seem to have records available. One explanation given to me was that since it was in July, it might be that in the monsoon period the sky was cloudy and this is as good a reason as any.

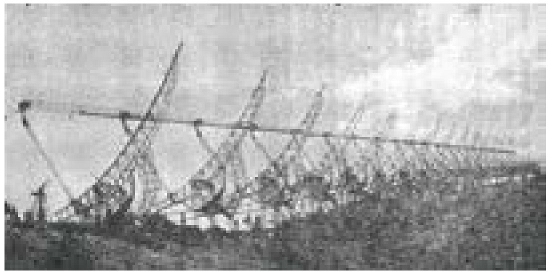
In the next slide is shown (Plate II, Fig. 5) the whole band of the Milky Way. It means if you look at the Milky Way which is the star system to which we belong, you will see that it is spread all round you and you may ask how many stars are there. The answer is that there are something like ten thousand crores of stars in the Milky Way system.

Let us see the next slide. It tells us what our galaxies would look like if we went on a space trip and looked at it from outside. This is our neighbouring galaxy, called ANDROMEDA (Plate III, Fig. 6).

This is another slide showing a galaxy further away than Andromeda and you can see that it has a spiral structure (Plate III, Fig.7). And this is why it is called a SPIRAL GALAXY. There are many galaxies of this type. Then there are galaxies which are elliptical in shape and they

are called ELLIPTICAL GALAXIES. There are also irregular galaxies which do not show any special type of structure. It is of interest because something
strange may be happening in it and the astronomer is always interested in extraordinary or strange phenomena which occur in our galaxy or elsewhere.

Now, so far I have been describing to you the Universe through pictures which have been taken with optical telescopes of the type which I showed to you right in the beginning; but this is not the only instrument available. After the Second World War, astronomers started looking at the Universe through a different window, as it were. They used the RADIO-TELESCOPE to measure and see what the Universe is like in the radio band of the electromagnetic spectrum and the interesting thing was that when they directed the radio-telescopes in different directions they got some very strong signals coming from certain regions of the space. So, just as you have galaxies all over the Universe of the type I showed you, there are things which are called the RADIO-SOURCES which emit the RADIO-WAVES which we can receive in the receivers of our telescope. Now, the radio-telescopes are always very big in size compared to an optical one. The reason is that the radio wave-length is considerably longer than the wave-length of visual light. And, therefore, to achieve the same degree of sensitivity in the technical term you have to have a much larger collecting area.



The radio-telescope at Ooty, operated by the Tata Institute of Fundamental Research

In the next slide (Fig. 8) is shown the radio-telescope at Ooty. You can see how big a radio-telescope can be. Indeed there are different types of radio-telescopes of different shapes and they do different jobs. The Ooty telescope is about km long and its axis is parallel to the axis of rotation of the earth. It is easier to build such a telescope closer to the equator than at high latitude. Now, one of the first radio-sources to be discovered was called CYGNUS A, as it was in the constellation of Cygnus. After its discovery, the optical astronomer wanted to see what was there in terms of visual light.

The optical photograph showed what at first looked like a pair of colliding galaxies. However, astronomers no longer believe in this hypothesis. They can now say definitely that there is no evidence of collision in the case of Cygnus A. In the next slide is shown the radio-source
C centaurus A, Plate IV, Fig.8) which is located near a big galaxy. The astronomers found that it has a central component which is showing signs of explosion and these explosions have posed an unsolved problem in the present-day astronomy. People want to know what these explosions are

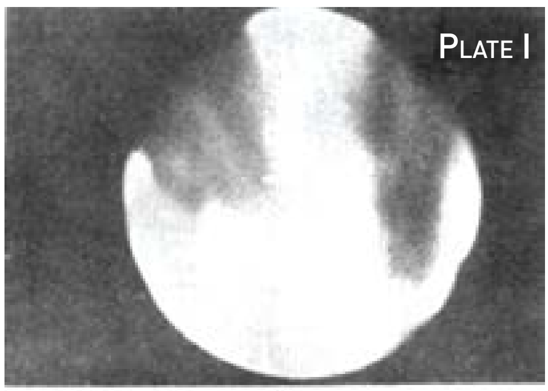
due to.

So far, I mentioned to you about optical (visual) astronomy and RADIO-ASTRONOMY. Let me now come to other branches of astronomy which became possible after space programmes materialised. The reasons are as follows:

So far as radio-waves and visual light are concerned, we can receive them on the surface of the earth without any absorption from the atmosphere in between. But these form part of a whole range of radiations which are collectively called the ELECTROMAGNETIC RADIATION and which have several different aspects. There are X-rays, γ rays, microwaves and so forth. Now all these other waves cannot be seen from the surface of the earth. So, after the space programme became possible, people could send up balloons, rockets, satellites well above the atmosphere and put in receiving instruments to get these types of radiation. In this way, in the last 10-15 years people began to look at the universe through the microwave, through γ rays, X-rays and so forth and this is yielding very interesting information.

One information that I can describe to you, which has become relatively popular in the recent days, is the so called discovery of a BLACK-HOLE. Let me first explain to you what a black-hole is and in what way one could claim that it has been discovered. Now you take any object, say, the earth. The surface of the earth has strong gravitational attraction for all the objects which are situated on it. If you throw any projectile or any ball in the sky it comes down because the earth's gravity pulls it. No, you can imagine the situation that the earth is made to shrink. What will happen is that on the surface of the shrinking earth the force attraction will go on increasing very rapidly. These days we have enough rocket power to send out a spacecraft from the earth's gravitational field. But this may not be possible with our present rocket-power if the earth was shrunk a little because it has now a stronger pull. So let us imagine this thought experiment and keep on compressing the earth and you can imagine that greater and greater rocket power will be needed to push anything away from the surface of the earth.

Now the quickest thing which travels in the universe, so far as we know, is light and light has no difficulty to get away from the surface of the earth. But can we imagine a situation where the gravity has become so strong that even light cannot escape from the surface of the earth?



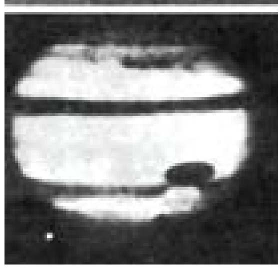


Fig. 2: The Planet Mars (Photograph : Hale observatories

Fig. 3: The Planet Jupiter (Photograph : Hale observatories)

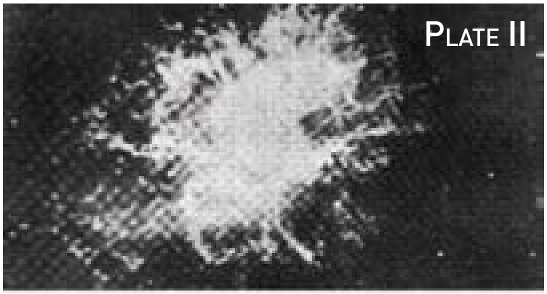


Fig. 4: The Crab Nebula (Photograph: Hale Observatories

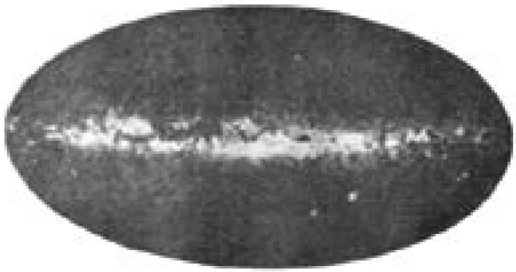


Fig. 5: The Milky Way (Photograph: Hale observatories)

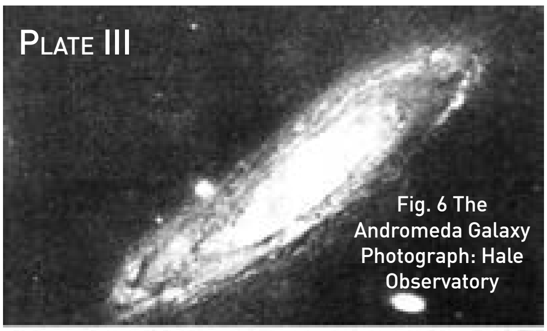


Fig. 6 The Andromeda Galaxy Photograph: Hale Observatory

Fig. 7: The Barred Spiral Galaxy (Photograph: Hale Observatories)

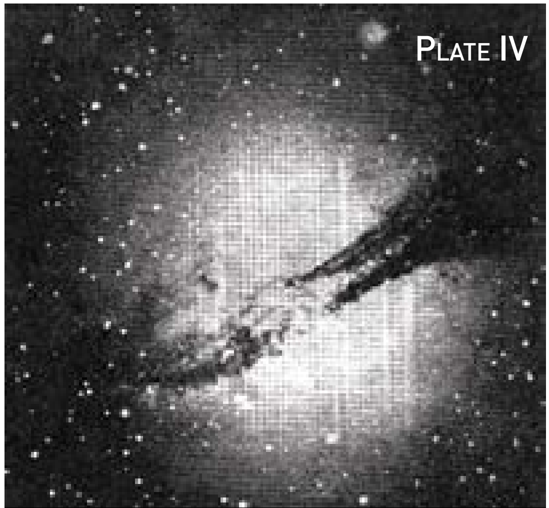


Fig. 8 Centaurus A, a Strong Radio Source (Photograph: Hale Observatories)

How much should the earth shrink in order that even light cannot escape from its surface? The answer is that it should shrink to a radius of about 0.8 cm. Imagine the whole earth shrunk to the size of a cherry. What happens then? So far as anybody outside is concerned, he cannot see this object (earth) because no light can come out of it. In order to see any object it should either be self luminescent or if you bounce light off it, (say, shine a torch light), it comes back to you. Either way, if light cannot escape from the surface of this object it won't be seen. So it is totally black and, therefore, it has been given the name of 'black hole'. The reason for calling it a hole is as follows— anything that approaches it, just falls in it and cannot come out. If there are black holes in the universe, how do we know of their existence when a black hole is not visible? It cannot emit anything that would reach you. And so if anyone comes and says that he has seen the black hole you can straightway say this is a lie, because you cannot 'see' a black hole.

Then how do you find that there are black holes in the Universe? Let us imagine another experiment. Suppose we compress the sun and make it a black hole so that it becomes invisible. It will continue to attract us; that is the earth will continue to go round the sun but we won't see the latter. But we can deduce the existence of the sun from the fact that we are not moving in a straight line. This is the principle behind the detection of a black hole that it exerts gravitational pull but it is not seen directly. The scenario where a black hole has been seen or is claimed to have been seen is the following:

Supposing you have got two stars going round each other (planets go round a star; you can similarly have two stars each going round the other). It is called a DOUBLE STAR SYSTEM. Now suppose one of them is a black hole and the other is a bright star. If you look on such a system you will see the big star going in a circle but about apparently nothing! You can calculate how much should be the mass of this particular object which is invisible. People have deduced the following things.

They have seen a thing which is going round about something which is not seen. What is more, this 'something' which is not seen is claimed to be the black hole. Now this black hole attracts matter from the other companion star and this matter is forced into this hole because of its attraction and in the process of pouring into this hole it becomes very fast, develops high temperature and emits X-rays. It is these X-rays which have been detected by the astronomers. Then they saw X-rays coming from a source called Cygnus X-I (that is, X-ray source in the constellation of Cygnus).

This X-ray source has been identified with a star which is apparently going round another star which cannot be seen. So the astronomers argue that this other thing must be a black hole. There are various theoretical reasons for supporting this conjecture but there are also equally good theoretical reasons for doubting this conjecture. Because, after all, all the theories are based on certain assumptions and when you come right down to the brass tacks, you find that there is always some kind of uncertainty in the assumptions. So, currently there is not a universal agreement among the astronomers that a black hole has been detected. But this concept of black hole has generated a lot of excitement among theoreticians because they can work out various theories or phenomena which are associated with the very strong gravitational field which is in the vicinity of a black hole. A lot of research in the last ten years has gone into black hole physics.

Along with this black hole idea there is another type of hole that people talk about. This is the WHITE HOLE. A black hole, as I mentioned, is something which is shrinking, and as a result, is becoming highly compact. The phenomenon of white hole, on the contrary, is an indication of an explosion which is taking place somewhere. Now I describe to you the case of Centaurus A which is a radio source. This concept of white hole would be relevant to those places in the Universe where the astronomer is detecting explosions which are not accountable by any other means. Again, this is not a concept which is fully established. People are trying to see how far it can be made to apply to what is actually seen. I would not like to say that this is a well-established fact. As in the case of black hole, here also is still some uncertainty. But both the black hole and the white hole form a very interesting aspect of modern physics which has been generated largely because of astronomical observations.

Now, so far I was talking about lifeless things in the Universe. And there is always a lot of speculation among the intellectuals on this earth as to whether there are intelligent human beings or intelligent beings elsewhere in the Universe.

Let us see what is meant by intelligent beings. The origin of life is broadly associated with those phenomena in nature where there is a generation of order starting from disorder. The reverse happens in the behaviour of inanimate systems. That is, if you take a cup and drop it on the ground it breaks. The original position of the cup was a well-ordered arrangement of molecules which finally became disordered.

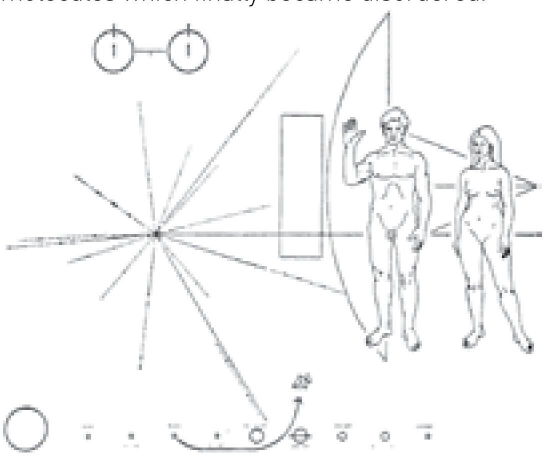


Fig. 9 : The Plaque in Pioneer 10 has information about the location of the earth and the human species.

In the physics of inanimate objects, the thermodynamic term ENTROPY has been used as a measure of disorder: the entropy always increases, or at most stays constant. Now where there is life, the reverse takes place. All kinds of chemical elements get together, form molecules and then they express 'life'. Wherever this happens one could say that there is a possibility of life. Now the nebulae which I mentioned earlier have been looked at by radio astronomers also and they find with their radio telescopes some very complex organic molecules in the space. This has led to increased interest in the last 2 or 3 years about whether these molecules indicate that life is actually possible and is being evolved in the outer space. Some scientists have conjectured what could be the conditions under which life could form in the Universe. For instance, one could go by the analogy of life on the earth and could say that there may be a star which has a planetary system and one of the planets has a suitable distance from the star, and it is hot enough or cold enough to generate life and then sustain it. You can make some very crude statistical calculations and estimate how many civilizations could exist in our Universe. The number of advanced super civilisations in our galaxy is estimated at a million. This has led to speculations as to how we can contact them or whether we should contact them or not, because it may not be to our advantage.

I will now discuss very briefly some of the procedures which have been advocated in trying to contact these extraterrestrial intelligent beings and we will see which is the best way to do it under the existing possibility, that is, our limited technology. The first thing that comes to our mind is now that we are entering the space-age why not design spacecraft and take astronauts on trips to long distances and see whether life exists elsewhere. Now if you consider the elaborate things that went on the lunar trip, that is, .in the outer space, you will realise that this approach is not very efficient.

What one should remember in this case is the following: if you send light to the moon it hardly takes a second or two, whereas this rocket took about a week to go and come back. Now, if you want to examine whether there is life in some nearby stars, some 3 or 4 light years away, light will take 3 or 4 years to get there. How long would the spacecraft take to go to such a distant object and come back? It will certainly take much longer than the human life time! So even if you want to explore the nearby stars for intelligent life, the matter of sending an astronaut, at least at present, is not feasible. You might devise some means of freezing the people so that they don't age as they go. They can go and come back after a thousand years and you may not be here to see them but they may come back with some information. But that is not a very practical point of view. So, let us take up the next idea which is to send unmanned spacecrafts. The unmanned spacecraft means the following:

You set up the scientific instruments and let them work for you. This is what was done for the landing mission to Mars. Likewise, the Pioneer 10 spacecraft was sent to go beyond the solar system. If you are lost in the sea you throw a bottle with some information in it and somebody can pick it up and then look for you. In the same way, this spacecraft contained information about the earth, 'written in a cleverly designed code (Fig. 10).

Here is another method which is as follows: Suppose two people are talking to each other and you listen through the key-hole. The idea is that you are, of course, not good enough to be admitted to their conference but at least the best you can do is to hear something. So you design the key-hole, which, in this case, is a gigantic radio-telescope. Because these signals are travelling they are supposed to be travelling over vast distances. So the suggestion is made, that you should simply design huge telescopes and direct them to outer space and hope for some meaningful signals to come.

One such project is called Project Cyclops, which consists of something like a thousand dishes each of a diameter of 100 metres. You can imagine how big this will be. You put this in a desert-like place which has no interference from anything else and let it just survey. You can use it to see if there is any pattern in the signals — codes of dots and dashes. If you get regular signals then you can hope for some intelligent sender behind it.

I have tried to give you some description of what the Universe is like, in as simple terms as possible. I would just like to remind you that all this information I am giving you is incomplete.

The best comment on this found in literature was a statement made by the famous astronomer Eddington long back in the 1920's. He compared man's position in the Universe with that of a potato bug in a potato inside a sack placed in the basement of a ship floating on the sea, trying to know what the sea is like. So, in the same way, we are in this planet of a solar system which is part of a galaxy and which is in turn a part of a system of galaxies in a small part of the Universe and we are trying to look, through all these limitations, what is beyond. What is encouraging in this is that such little science as we know can form a coherent picture. We should not delude ourselves that this is a correct picture or a complete picture but it is a coherent picture which is emerging. Maybe, it will form the first step towards a better picture that our successors will evolve. This is therefore a subject of enormous and growing interest and if you invite me to give another lecture on this topic ten years later, I may have something completely different to report on this subject.

STAR-GAZER HERSCHEL

One of astronomy's commanding figures was just an amateur when in 1781 he startled the professionals with his discovery of the planet Uranus (the seventh planet).

Since the days of Galileo, no telescopic find had created a greater sensation than Uranus. Before Herschel became world famous as the discoverer of the planet Uranus, he was almost completely unknown in professional circles... He was, in fact, a musician...who had only been engaging in astronomy as a hobby for a very short time...

He employed a completely new type of telescope, so unusually wide that a man could put his head into the tube. The metallic mirror at the lower end was twice the size of all known telescopes...His method of searching, what he called sweeping, was also an important factor in his great discovery. Every night he took a strip of sky of about two degrees. He went through it twice in order not to miss anything...

In all fields he outstripped his colleagues. If some German found a few dozen binary stars, Herschel discovered several hundred. If a Frenchman listed sixty nebulae, Herschel soon afterwards published a catalogue of a thousand.

At the age of thirty-six he became the music master at Bath...After his fourteen-hour working day as a musician, he sat up half the night reading enthralling books on the calculus of fluxions, theoretical optics and mathematical astronomy.

–Science, Science, Science, selection by Russell Hamilton, Frankon Watts 1960

INDIA'S CONTRIBUTION TO ASTRONOMY – RELIGIOUS AND HISTORICAL BACKGROUND

S.C. Chatterjee
Kalimpong, W. Bengal

In the dawn of civilisation people must have had a rudimentary knowledge of time and space, and all the ancient scriptures regarded the universe as consisting of a flat circular earth below and a heaven above through which the sun, the moon, and the stars move. Between them was the middle air, the abode of clouds and demigods. This cosmological picture was considerably changed by later religious thought, but the heavenly bodies were still worshipped as gods. In India the Rig Veda mentions that observatories were erected for astronomical purposes, as the practice of sacrificial rituals demanded the setting up of altars for religious performances, and therefore some astronomical knowledge was necessary for determining the propitious times and dates for periodic sacrifice. Thus some astronomical knowledge became necessary. Like the Babylonians and the Greeks, the Indian priests also kept detailed records of the rising and the setting of various celestial bodies, and thus established a kind of calendar; but without a clear idea of cause and effect. It was but natural that Divine Will was recognised, and the heavenly bodies were regarded as gods. A general belief in astrology was the natural consequence.

During the Upanishadic period, the Brahmana, and the Aranakya periods even those philosophers like Kanada, Gautama and Charvaka whose motives were scientific rather than religious were hardly in a position to drive their speculations home to the point of proof against their scriptures. They tried to get their ideas stated in a consistent and plausible form and had to see how far the results tallied with the experiments of common experience. Considerable progress was made in their observations of the heavens and the inexorable mathematical laws and rational science gave greater prominence to astronomy than astrology. Heaven was, however, still regarded by most people as a place where gods had their abode; and without a systematic layout of planets and stars there could not be any great progress in astronomy and the original rational impulse behind enquires into Nature began to evaporate and disappear. If the planetary system had been properly worked out, and scientific reasoning and the worship of natural laws given preference against the semi-human divinities of the sky, the universe would have been regarded as a vast organism cemented into a coherent unity by sympathetic forces, with Nature as the guiding principle, and the celestial bodies as its purest expression. Instead, the astral religion, specially of Greece and Babylonia, kept its hold; and a proud and long tradition of astrology was maintained intact. Astronomy was made more subservient to it than to physics.

As time rolled on, the system of astrology in India reached its scientific maturity and began to be regarded as a social science, and astronomy a natural one. It has been argued that since astrology deals with material things, it is bound to
be imperfect owing to human frailty; but astronomy gives clear-cut results and hence is reliable.

Foreign Contribution

In the domain of astronomy the Egyptians claim to be first people who divided days and night into twelve hours and invented water-clocks which they used specially in the night for knowing the time. They used sun-clocks during the day, but in astronomical observations they hardly made any progress. The Babylonians, however, went much further. They invented an improved form of clock known as the water-clock by collecting water from one sunrise to another and by dividing the water into equal parts. It is not clear why a day and night of twelve hours each and not of eight or ten hours were taken. Apparently a compromise was made and the sexagesimal division of the Babylonian units was combined with the Egyptian twenty-four system. They made more progress, observed and recorded the apparent motions of sun, moon and the planets, but hardly formulated any theory to account for their movements. It is here where the Greeks and the Indians showed their geniuses.

Anaxagoras, who was born about 500 B.C. near Smyrna, left his possessions in order to study science and went to live at Athens. It was he who first discovered* that the moon has no light of its own, but shines by reflecting sun's light. With Anaximines he correctly accounted for the eclipses of the sun and the moon. He also gave some fruitful ideas about the nebular hypothesis on which our present cosmological theories are based. He, at the same time, conceived that there are other worlds like ours; but apart from these ideas he hardly made any advance upon the crude astronomy of his time. Both Leucippus and Democritus, who formulated the atomic theory followed the views formulated the atomic theory followed the views of Anaxagoras and made in advance in the astronomy of their time.

About half a century later, Aristotle supported Eudoxus and Callippus and regarded the universe as spherical in shape and finite. It was about 200 B.C. when Aristarchus (310-230 B.C.) first gave the heliocentric idea of the astronomy of his time.+ The historian Plutarch says that for giving a pagan's hypothesis of our universe he should have been indicted for impiety; but since the leading mathematicians of his time like Archimedes and Seleucus did not preach against him, no action was taken. Perhaps nobody cared to know his impious declaration.

It was however Hipparchus who totally discarded Aristarchus's heliocentric hypothesis and adhered to the prevalent geocentric system. He

In India Aryabhatta conceived that same idea of the planetary system, but he did not dare go against the general belief of his time.

+ The present writer does not think that either Aristarchus or Copernicus got the heliocentric idea from India; but Heracliedus of Pontus was certainly foreshadowed.

made accurate observations of the heavens, his greatest achievement being the discovery of the Precession of the Equinoxes. He also calculated the length of the year as 365-$\frac{1}{4}$ days. Based on his extensive observations Ptolemy, who wrote his famous Almagest in about 150 A.D. held the field till the time of Copernicus who later supported by Galileo, Kepler and Newton, changed the entire conception of the universe.

Later Development

Aryabhatta I was perhaps the first mathematician who, having based his ideas on the teachings of the sage, Parasara, propounded his astronomical system but the author of the extant Aryabhatta that deals specially with mathematics and astronomy, is likely to be another Aryabhatta whose astro-mathematical works, known as Arya-Siddhanta, lived at the end of the fifth century A.D. He was a great inventor who boldly discarded all astrological predictions and sought to reform astronomy on scientific principles.

It may be mentioned here that Aryabhatta, like Aristarchus of Samos who had boldly rejected Eudox's vortex idea, maintained the idea of the rotation of the earth round its axis and gave the idea that a similar phenomenon would happen if the sun was regarded stationary at the centre, and the earth and other planets were to revolve round the sun. His estimate of the earth's circumference was not very wide of the mark. For the purpose of calculations, however, the planetary system was taken as geocentric and the later astronomers accepted this idea.

The younger Aryabhatta was followed by Varahamihira who was probably born in the beginning of the sixth century A.D. He was an all-round scientist who wrote several well known works of which the Pancha Siddhanta treats both astrology and astronomy that include the computation necessary for finding the position of a planet. He discussed the sphericity of the earth and subsequent astronomers followed him. Alberuni translated two of his works into Arabic in 1000 A.D.

It is said that while summarising his astronomical theses, he was helped by some Scythian Brahmans who were well versed in Babylonian and Greek astronomy. It is very speculative on our part to say how far the great Indian astro-mathematician received his astronomical information from the Middle East countries. It is also possible that the same type of ideas has originated in different countries much at the same time, as we find in the case of the independent discovery of oxygen in different Western
countries – France, England and Sweden.

Another prominent Indian astronomer was Brahmagupta (born 628 A.D.) who lived at Ujjain, then a great astronomical centre of India. It is said that unlike his great predecessor of encyclopaedic knowledge, he was a more original thinker who separated astronomy from astrological speculations although he had made various astrological charts and reformed astronomy on scientific lines. It is recently said that he invented the quadrant (Turya Yantra) for astronomical observations and applied algebra to astronomical calculations. In a few decades the Caliphs of Bagdbad made use of this scientific invention in their astronomical observatories.

A few centuries later, although the Medieval Age had set in India, there was born in 1114 A.D., a world-renowned astro-mathematician of prodigious scholarship, popularly known as Bhaskaracharya, who also worked at Ujjain. His treatise, known as Siddhanta-Siromani, contains: (i) astronomy, (ii) arithmetic and mensuration known as lilavati and (iii) bijaganit (algebra). In his studies on the earth he gave its diameter as 7905 miles and mentioned its attractive power, thus forestalling Newton by several centuries. He also determined with considerable accuracy the positions of the sun, the moon, and the planets in terms of their positions on March, 19 1520.

Like the Buddhist monks there was a host of Indian astronomers who did missionary work in Middle East countries. For instance, patronizing the Persian school of astronomy, the Second Caliph, Al-mansur, in 723 A.D., invited to his court the renowned Indian astronomer, popularly known as Manaka, who gave various tables of equitations of planets according to their motions with observations relative to both solar and lunar eclipses, as well as the ascension of the signs. It is also said that the illustrious astrologer, Abu Mashar of Balkh, depended much on another Indian astronomer well-versed in the science, learnt from him the great cycle of 'kalpa' and applied it for his astrological calculation. Besides, Brahmagupta's two well known astronomical works, Brahmanasphuti Siddhanta and Khandakhadyaka, were translated into Arabic and named as Sirhind and Arkand. They exercised great influence in imparting scientific knowledge of astronomy in the country, and the great mathematician, al-Kanaurizi, further developed the Indian astronomical system in his country. A few years later another Saraconic mathematician, al-Kindi, laid stress on the used of Indian numerals and astronomical tables. The Third Caliph, Harun-al-Rashid, set up a House of Wisdom for the translation of Greek and Indian works the chief translator being the Nestorian Hunaya-ibn-Ishaq (809-877 A.D.) and also founded an astronomical observatory at Baghdad with the help of Indian astronomers.

For a few centuries however, Baghdad remained the great centre of mathematical and astronomical studies. Religious tolerance and official patronage keep alive an active interest in Nature; but her golden days did not last long, for the Mongols soon overran the Middle East, and in the twelfth century sacked Baghdad. From the thirteenth century onwards, Mohammedan power began to decline, and rational enquires in science and philosophy were condemned as corrupting the truths of Islam. The scientific tradition in the Sarcacentic countries began to dwindle and their knowledge was taken to Europe.

Like her renowned neighbour, India's days of glory were also numbered, and although, for some centuries, great mathematician, and astronomers like Bhaskara made valuable contributions, their outlook was, like Newtons, chiefly theological. In the thirteenth century practically the whole of northern Indian was overrun by the bigoted Pathans, and the educational institutions like Nalanda and Vikramashila were razed to the ground. Like the Islamic world India also sank into oblivion.

Generalisation

The Early cosmology in India, like that of Greece in her golden age (500-300 B.C), took the form of dramatic historical fables known as Puranas. In the beginning, the heavenly bodies were regarded as gods, but during the later period attempts were made to explain the structure and behaviour of the heavenly bodies in scientific terms. The Upanishads put forward theories of natural happenings and have thus laid the foundations of philosophical science. As a result the different schools which started in with vague ideas of creations gradually brought general scientific theories into precision; but unfortunately, scientists like Patanjali gradually lost faith in themselves, and their methods of thought changed direction. They began to doubt more and more if scientific enquiries along could unfathom the workings of the universe, and gradually the centre of gravity shifted from natural philosophy to unaccounted Divinity. The heavenly bodies thus again came into prominence and because objects of worship, as they had been before in Egypt and Babylonia. Astronomy thus became more subservient to astrology than to physics and dynamics. As a result, a sophisticated kind of heaven-worship began to replace the rational speculations about Nature, and a faith in divination began to revive; but in India the spirit of rational investigation soon returned a few centuries after the Chritistian era, and her astronomers showed definite superiority over her celebrated rival (Greece) in calculating the solar year and in recording the progress of the moon through the sky with an accuracy which was not surpassed until the seventeenth century A.D. In 1787, J.S. Bailley* published his treaties about the great antiquity of the Hindu astronomical system. He believed that their calculations, made from time immemorial, were infinitely more exact and natural than those of Ptolemy: and that the Greeks of Alexandria had profited by the Indian thoughts, but had mutilated their results. Bentley, on the other hand, holds a different view.

For the purpose of astronomical calculations the planetary system was taken as geocentric, although it was suggested in India long before Aristarchus that the earth revolved round the sun and also rotated round its axis. The true cause of solar and lunar eclipses were also properly explained, and the occurrence of both the eclipses were forecast with great accuracy. The later astronomers like Varahamihira, Samudragupta, and Bhaskar also accepted the heliocentric idea, but did not bother to preach it to the public. In short, the Indian astronomical formulations were more reliable than those of the Graeo-Roman world for all practical purposes.

Conclusion

In summarising it may be stated that unlike the Babylonians and the Egyptians who only cared for the continuity of their astronomical records for the maintenance of a reliable calendar, the Indians of antiquity went deep into the matter and tried to theorise all the natural phenomena which they had come across. Their astronomy has three definite phases: (a) Vedic Astronomy, which is unscientific, (b) Vedanga, Jyotisha which is formal but crude;

*Jean Sylvain Bailley was the first mayor of Paris and President of National Assembly in 1789. He was born in 1736 and guillotined in 1793.

(c) Siddhanta Astronomy, which is highly intellectual. No doubt, some of the astronomical problems of the present time were not clear in those days; but the Indian astronomers did lay the foundation, the generalisation on which during the sixteenth and seventeenth centuries became the main feature of the rapid development of astronomy in the West. To be brief, astronomy and mathematics led the way and physics followed it in the seventeenth century. Chemistry moved forward in the eighteenth century, biological sciences in the nineteenth, and atomics science in the twentieth century.

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A PORTABLE NANOGONAL ROTATING HUT FOR OBSERVATIONAL ASTRONOMY ACTIVITIES IN SCHOOLS AND COLLEGES

Ved Ratna

Former Professor, National Council of Educational Research and Training, New Delhi
Honorary Director
Mann Observatory
C/o Mann Public School, Village Holambi Khurd
Delhi-110082

Any systematic study of celestial bodies usually necessitates a series of observations spread over several days or even weeks. Thus, if serious use of a telescope is being planned in an educational institution, it would be better to permanently install it at the desired point (terrace or open field), at least for the duration of a particular project.

Need for a Low Cost Observation Hut

The appearance of Halley's Comet in 1985 has aroused much interest in observational astronomy activities among school and college students in India. However, lack of proper guidance materials and facilities has been one of the major constraints to sustain this interest. Thus, there is an urgent need for providing necessary facilities for observing the night sky within the school/college premises or at another suitable venue. The proposed observation hut would not only fulfil this requirement but would also provide scope for conducting many activities based on astronomical observations. The salient features of the observation hut are:

(i) preventing any health hazard to children from cold winds, and

(ii) preventing vibration of the telescope caused by wind, in case its stand is not strong enough.

This need is particularly important in Northern India. It is because that the proper season when the sky has minimum dust and clouds and when children also have time for co-curricular activities is after the rains, that is, from October to January, which is also the coldest part of the year.

Apart from providing protection from the vagaries of weather, the observation hut also provides facility for permanent and proper setting of the telescope besides its easy manoeuvring for making systematic astronomical observations. Theoretically, a telescope can be used just by carrying it to an open place which can be an open compound or the terrace of the school. However, in order to make a meaningful use of the instrument, its polar axis has to be set parallel to the axis of rotation of the earth. To make this adjustment accurately is a bit time consuming task. Time and effort spent in making this adjustment can discourage some students who wish to attempt some activity or do project work with it. Any systematic study of celestial bodies usually necessitates a series of observations spread over several days or even weeks. Thus, if serious use of a telescope is being planned in an educational institution, it would be better to permanently install it at the desired point (terrace or open field), at least for the duration of a particular project. In such situations it may become necessary to protect it from adverse weather conditions like rain, dust, excess humidity, etc. A suitable housing for the telescope is, thus, quite necessary.

The nanogonal shaped observation hut described below combines maximum usable inside space with light weight, stability and easy transportability. It uses simple technology which is available everywhere in India. It can be easily constructed by any school with the help of local craftsmen.

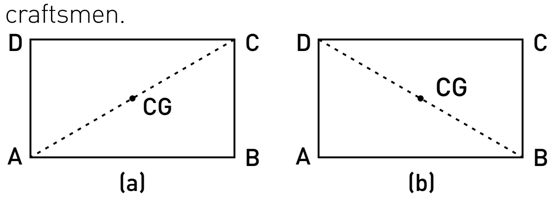

Fig. 1. Possible triangular bases of a four-legged object

This observation hut can also be used as a general purpose circular tent, when its wheels are not fitted in it and the circular wall-cum-bench, about which it rotates, is not constructed.

Why the Nanogonal Shape of Observation Hut?

(a) 3-, 4- and 5- legged objects: Consider first the case of a common item of furniture like a table or a chair, having four legs. Quite frequently, when it is placed on an uneven ground, it is found to be swinging on one of its diagonals. It happens as follows. On an uneven ground, only three legs touch the ground at one time. All possible combinations of three legs in a furniture whose four legs make a rectangle, are right angled triangles. We may take any of these triangles (Fig. 1), the centre of gravity (CG) of that item of furniture lies on the diagonal of that triangle. Thus any slight force swings that furniture over to another triangular base.

Solution of this particular problem is found commonly in having three or five legs, as in case of tripods used in science laboratories and five- legged executive chairs with wheels. At this point it would be interesting to discuss the use of pentapods instead of tripods in the science laboratories. It may be argued, referring to Fig. 2, that in case of pentapod a triangle like ACE (Fig. 2-a) always forms the triangular base on which apparatus stands. In addition, the two legs B and D serve as a second line of defence against toppling over of the apparatus. If by any chance the apparatus tends to topple, say, over the line AC, then the leg B touches the surface of table and thus attempts to prevent the toppling. In case of tripod, there exists no such second line of defence.

(b) The Case of Rotating Observation Hut: Consider now the structures which serve the purpose of circular structures. Octangular tables are so common alongside the circular ones. Amateur astronomers have used octangular rotating huts. The author too, first tried the model of an octangular rotating hut. When it was put on various uneven surfaces, it was found that frequently, though not always, it swings about a line vertically below its CG. Hence the need for a septangular or nanogonal shape of rotating observation hut arose. A hut which keeps swinging by slightest wind would be quite distracting and may cause minute vibrations of telescope, which may make astrophotography impossible.

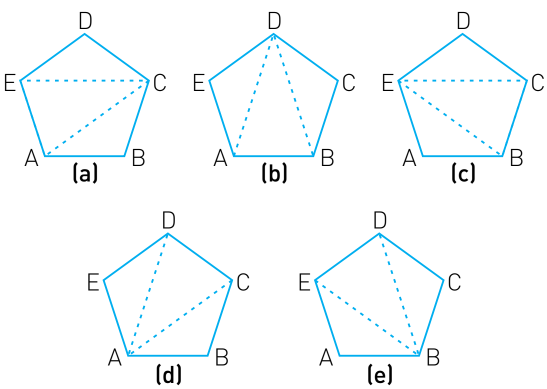

Fig. 2. Possible triangular bases of a five-legged object

To decide between the two options (7 or 9 sided hut), three criteria were considered:

(i) What are the various possible triangles (which include the C.G. within it) made by joining any three corners of the polygon? Does the C.G. lie on a side of any of the possible triangular bases? If it so happens in a particular shape, then that shape would be unacceptable. On this criterion, all regular polygons with even number of sides are unacceptable.

(ii) What is the probability of each possible triangle becoming the base of the observation hut on an uneven ground? What is the weighted average area of these triangles? The larger the weighted average area, the better it is.

(iii) What fraction of the area of circumscribed circle of the polygon constitutes the inscribed circle? Only the inscribed circle is the usable area in which the students can work. Hence, the greater this fraction, the better it is.

An analysis of the various shapes in consideration here, with odd number of sides, on criterion (ii) is given in Table 1. Figure 3 shows the various possible triangular bases with vertex V, for each shape of observation hut. On this criterion, the triangle comes at the top, which justifies the use of this shape in science laboratories where criterion (iii) is not relevant.

Sl. No.	Observatory Shape		Sides of Base Triangle (m)	Area (m^2)	No. of Triangles for Each Vertex	Probability of Occurence	Weighted Average Area of Triangle (m^2)	Incircle	
								Circum Cirle	Figure No.
1	Triangle		4.33 4.33 4.33	8.119	1	1	8.119	25%	3(a)
2	Pentagon		2.939 4.755 4.755	6.645	1	1	6.645	65%	3(b)
3	Septagon	(a)	2.169 4.875 4.875	5.157	1	1/2	6.303	81%	3(c)
		(b)	4.875 3.909 3.909	7.450	1	1/2			3(d)
4	Nanogon	(a)	1.710 4.924 4.924	4.146	1	1/4			3(e)
		(b)	4.330 4.330 4.330	8.119	1	1/4	6.492	88%	3(a)
		(c)	4.330 4.924 3.214	6.852	2	1/2			3(f)

Table 1

Possible Triangles formed by Wheels in Contact with an Uneven Ground for Various Observatory Shapes

Diameter of circumscribed circle = 5 metre

Area of circumscribed circle = 19.635 sq. metre

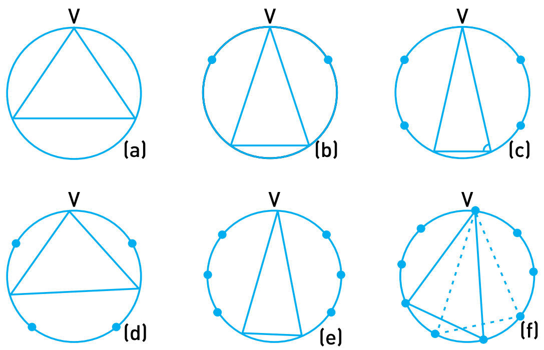

Fig. 3. Possible triangular bases with vertex V for 3-, 5-, 7- and 9- legged observation huts

Between septagon and nanogon, the latter is better on criterion (ii). Hence it was decided that nanogon is the appropriate shape for rotating observation hut.

Last column in the table gives the fraction of area of circumcircle, which constitutes the inscribed circle. This fraction also is the highest for the nanogon. With this fraction at 25%, the triangle shape seems to be totally unacceptable for the rotating hut.

It is noteworthy that both on criterion (ii) as well as on (iii), there are no vast differences among pentagon, septagon and nanogon. For use in a school/college, where there may be occasions when you want 25 to 30 students at a time to be in the observation hut and thus a diameter of 5 metre is needed, the author recommends the nanogonal shape. But in smaller diameters, septagon and pentagon may prove economical in terms of time and labour spent in its construction.

Description of the Nanogonal Observation Hut

It is built on the base nanogon AB....HI (Fig. 4). This nanogon bears the entire weight of the observation hut. Each corner also carries a short bar (not shown in the figure), which functions as a bracket so that the angle between the adjacent sides of the nanogon meeting at that corner remains rigid at 140^0. Each short bar also has a wheel fixed below it. On these nine wheels, the entire hut can rotate around a circular wall-cum-bench. The load bearing wheels move on a circular iron track, or on a cemented floor (in which case the wheels must have rubber tyres too).

There is a horizontal decagon JK......RS, in which the side RS (S. No. 18) is just a thin wire. All the other sides are strong bars, i.e., thick hollow pipes so that these are strong and yet of light weight. This horizontal decagon is supported on the base nanogon by 20 bars, serial nos. 33 to 52. Out of the 19 triangular faces made by these 20 bars, 17 are almost equilateral triangles and two are right angled triangles, so that the last face RSWV is a rectangle. All the 20 standing faces are close to vertical, but slightly inclined inwards. The rectangle RSWV forms the gate through which students and teachers can enter the observation hut. Its width can be kept whatever desired up to about 75% of the length HI.

The horizontal bar TU is the highest component of the entire hut. It is supported above the horizontal decagon JK....RS by twelve bars (serial nos. 21 to 32). Rectangles TUSR and RSWV together form the slit through which telescope, placed inside at the centre of the base nanogon, can se the sky from horizon to zenith, Z. The thin wire RS does not form on obstruction in the field of view of the telescope, whose objective may be of 62 mm or more in diameter.

The entire hut, except for the slit TVSWVR, is covered with a water-proof tapaulin cover of light weight. With wheels having ball bearings, the hut can be quite easily rotated by two persons in order to change its orientation whenever desired, so that the telescope can be fixed to observe another part of the sky.

When the hut is not in use, the slit TUSWVR can be closed by two tarpaulin curtains, one covering the rectangle TUSR and the other covering the rectangle RSWV. Each curtain opens at the wire RS, so that when observations are done, only the thin wire RS is in the field of view of the telescope.

In spite of this covering on the slit, the telescope inside the hut cannot be considered to be completely safe when not in use. Hence it is advisable to remove it when it is not being used. The stand of the telescope can be left undisturbed inside the hut, so that its polar alignment need not be done again, at the time of next observation session. The stand should further be covered by a large polyethelene bag, in order to minimise any chance of water drops or dust reaching it.

Sturdiness Considerations

The basic structure of the observation hut is almost as sturdy as a geodesic structure, though it does not in any way resemble the geodesic structure. All the faces of this structure are triangles. Seventeen of the twenty standing faces are approximately equilateral triangles.

The tarpaulin cover is, of course, a weak cover. It is alright for a short period of a month or so, when the weather is expected to be fine. It has to be properly maintained too. It must be mended, if and when it gets torn at some spot. Thus the hut is basically a circular movable tent.

If so desired, a sturdy permanent observatory of similar design as this hut can also be constructed by:

(i) covering it by metal sheets instead of by tarpaulin;

(ii) using angle iron and T-iron bars in place of hollow pipes for making the structure, because when holes are drilled in pipes and metal sheets are screwed on them, seepage of some water into the pipes will cause much rusting as it cannot evaporate; and

(iii) welding the joints of the bars instead of making them by nuts and bolts.

The study structure made in this manner can withstand a wind storm too. However, its weight becomes inconveniently large for moving it manually. Hence, either it may be driven by an electric motor, or it may be constructed in a smaller diameter of 4 metre or 3 metre for fewer students to be inside at one time.

Due to the large slit in it, this structure may be considered to consist of two halves WIABCD and DEFGHV. The two halves are held together by the nut-bolt D, the wire 18 and the bars 8, 20, 13, 31 and 32. The stresses are such that the wire 18 is almost always in tension. Thus a thin wire serves well at this spot, instead of thick bars used in the rest of the structure.

Lift Due to Wind

In spite of all the standing faces of the structure being slightly inclined inwards, there is a lift acting on it when there is wind blowing. Suppose at some occasion wind is coming from the left (Fig. 4). Then over the right half WIABCD, a reduced pressure is developed due to Bernoulli's principle. Thus the right half of the hut tends to lift up. So we have to make some arrangement by which the structure can be prevented from lifting off the circular track in strong wind. A simple arrangement is as under.

Outer diameter of the circular wall-cum-bench

= Diameter of inscribed circle – 2 X size of horizontal wheel.

Let this be the diameter of the lower part of the wall only. About 2 cm or 3 cm above the base nanogon, diameter of the wall may be increased and made more than the diameter of the inscribed circle. It has still to be less than the diameter of the circumscribed circle, because the superstructure rests on the nine corners of the base nanogon. Thus the lower part of the wall has a sort of groove into which horizontal wheels and centre point of each side of the base nanogon moves.

Transportability of the Observation Hut

The structure is capable of being used as a portable observatory, when constructed by light weight bars and tarpaulin cover. It can be easily dismantled by opening just 32 nuts and bolts, and can be easily reassembled at any venue where observation work is desired to be done. Nuts and bolts are not just 23, as would appear from Fig. 4. At each corner there is a short bar carrying the wheel for that corner. One end of the short bar is welded and the other is fixed by nut and bolt.

The circular wall-cum-bench, which anchors the hut in strong wind and around which the hut rotates, is obviously an immovable structure. Thus in transporting the hut to a new venue temporarily, this wall has to be constructed at the new venue. Afterwards, this wall-cum-bench can serve some other purposes in that institution. If that institution does not like to have this wall constructed, then the hut can be used in not-so-strong wind, which does not lift it up. When not in use, the hut can be anchored by simpler means, e.g., tying it down to three heavy objects which make approximately an equilateral triangle.

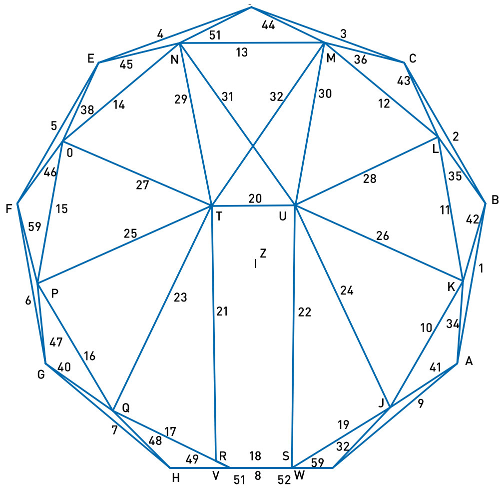

Fig. 4. The basic structure of bars, as seen from above, for constructing the Nanogonal Rotating Observation Hut.

Guidance to Institutions for Constructing a Rotating Observation Hut

If any institution proposes to construct an observation hut of design as discussed above, the author and Shri Anurag Gupta, a reputed architect of Delhi, are in a position to provide guidance with the help of a fully functional scale model. A decision must first be taken by that institution about

(a) venue of the observatory (terrace or an open area where maximum sky is visible);

(b) whether it is intended to be a portable observatory or a sturdy permanent one;

(c) what is the maximum expected number of students who will be inside the observatory at one time;

(d) what size of observatory (diameter of inscribed circle) is desired in view of information (c) above and in view of the size of telescope available in that institution.

Acknowledgements

The development of this design of observation hut was done by the author during past few years. Much work was done when he was still in the NCERT, where help was taken from the then Head, Workshop Department, Dr P.K. Bhattacharya and technicians working with him. They constructed several models with which the author experimented. Grateful thanks are due to them. Thanks are similarly due to physics laboratory staff of the NCERT.

Grateful thanks are also due to:

(a) Shri Anurag Gupta, a reputed architect of Delhi,

(b) Shri S.C. Tapde, formerly Project Manager for the telescope at Kavallur constructed by the Indian Institute of Astrophysics, Bangalore,

(c) Dr. M.K. Tiwari, Indian Space Research Organization, Bangalore, and the Vice President, Bangalore Association of Amateur Astronomers,

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APPLETON, A.K., 'A Home-built Rotating Observatory'. J.B.A.A. vol. 68, No. 6. page 217.

(d) Dr. (Mrs.) N. Raghavan, Director, Nehru Planetarium, Teen Murthi Bhawan, New Delhi, and

(e) Dr. R. Swaminathan, Associate Astronomer, Centre for Advanced Study in Astronomy, Department of Astronomy, Osmania University, Hyderabad,

for their valuable advice in designing the above described observation hut, when the author met them during official tours of the NCERT.

After author's retirement, his wife deserves appreciation for tolerating the boredom when the author would neglect normal attention to the home and indulge in so-called "research".

AN URGENT NEED FOR INCLUSION OF GIS IN THE CURRICULUM OF GEOGRAPHY AND COMPUTER SCIENCE

Prasanta Mali
Ashok Kumar Singh
Department of Science and Technology
Technology Bhawan, New Mehrauli Road, New Delhi

In our country some of the latest developments in technologies in many of the educational fields are not incorporated at the right time. Sometimes they are not recognised as simple initial stages. But, if seen deeply, it will be revealed that they are very fundamental in the context of growing computer education and their applications. In the present day situation, many subject areas at the stages of elementary education lack proper emphasis on important applications desired. These applications will not only make that subject more interesting to the students but also attract many talents in that area. We would see that same contents are actually being taught in different stages at the school level in the present curriculum. Perhaps the one being suggested here exists but not in a form desired in the present day situation.

The application of GIS – Geographical Information System technologies in the curriculum of Geography at the school level. Though it may initially sound to be something from a higher platform, but with the changing character of education this would emerge as an indispensable area for the subject. Its inclusion would not only change the character of the entire subject of Geography as a science of the Earth, but also help the country to collect the maximum data needed for the micro level planning for the country planners. It is still seemingly obscure but through this dissertation we would like to emphasise that it is inevitable in the present day situation. Inclusion of GIS in the curriculum will make the study of geography very exciting and useful. More importantly the data acquisition will become very easy. There will be mass involvement of the education system in data collection process. Enormous quantities of accurate data will flow from various institutions with the latest updations. Both the objectives of data collection and organisation will met without extra effort in collecting data.

What is GIS after all? Now-a-days all students are taught what are maps and to what extent they are informative, etc. Think of a map which will give everything and anything whenever you want! Is it not something interesting? Think of geography with all the information you need! The information of a particular man of a country, his state, district, town, his locality then his own house and himself. Is it not exciting! We will be just crazy to have such an exhaustive coverage of the subject. This will give everything that will be geographical information about the near surface, above and below the Earth, such as elevation, temperature, population, density, literacy, occupation and resources of different types. It will be more so when we know that such things would be possible by application of computer software usage that is especially prepared for this purpose. This software is readily available for their useful application. It is not a dream now. Besides all these, we can be a part in creating this information base and facilitate in further development.

Let us know what GIS is. G- Geography (The Globe, near-earth, above and below, Map, Layers), I- Information (Physiography, Hydrogeology, Soil, Land use, Resources, Socio-economic parameters), S- system (Computer Hardware, Software, Database Libraries). It is presently seen as the most versatile technology option for the policy makers. Spatial Decision Support System (SDSS) is entirely dependent on the relational databases. When the relational databases are easily available for the entire country at the micro-level it would not be difficult for the economists and managers to arrive at the optimum solution for any kind of problem.

If the present stock of situation is taken, we will see that the education system has introduced quite a bit of computer learning in the curriculum. The exposure and the use of computer begins quite early. In many parts of the country the tie-ups of the schools with the computer training institutes has improved the learning process, too. Now what remains is utilisation of the knowledge and application in proper area that would change to a large extent. Presently, the course of geography invariably contains preparation of maps as a core element, with all the elementary methods dealing with scales, etc. Actually these are also the basics of the preparation of the software with slight application of mathematical principles in various type of maps with layers, supplemented with exact latitude (Lat) and longitude (Long) data that could be collected by using a Global Positioning System (GPS). Maps and map layers are easily dealt where each layer of a map means information on any of the criteria or parameter like roads, watersheds and run-offs, power plants and soil type. If dealt properly, perhaps it would not be difficult to understand that more useful application software also could be developed once the GIS is introduced in its real essence in the course content of geography.

What is the current status of GIS applications? It is quite well-developed and prepared for make its appearance as a key element of the course content of Geography, Geology and Geophysics. Many commercial conversions are available at present of use. Some of these are Arc Info, Arc View, Map Info, Arc GIS and GRAM++. The first four of the software/applications have been in use for quite some time while the package of GRAM++ has been developed indigenously by Scientists of our country. This can be very judiciously used for education and training at different levels and would not be a very expensive affair in any case.

As expected the GRAM++ an acronym for Geo Referenced Area Management also have incorporated many features that would attract any of the students of Geography, Geophysics, Geology, Civil Engineering and Geo-Science. This is a PC-based package that runs on Windows 9x/NT environment unique for its user friendliness. The key features among these are – drawing of maps on different scales representing them in either Raster form and Vector form depending on the requirement. The Raster form is the usage of scaled pixels for maps. Whereas the Vector form gives the position with respect to a reference point in a frame. The maps thus can have points, lines and polygons. Using raster and vector data it is possible to prepare layouts for visualisation. The cartographic outputs can be obtained by using labels, legends, symbols etc., with desirable scales and projections. GRAM was initially developed after the study and usage of the existing packages have been developed in the Indian context suitable to the existing conditions and the kind of requirement that are often to be taken into account. It has also been revised according to the requirement while using it for various purposes resulting to GRAM++. Since the package involves so many other tools than the ordinary map editing or importing and exporting of data. The positional and non-positional data are very nicely manipulated for the graphical representations and outputs desired. Many features exists beyond the map digitisation and its relational databases. Its use as a decision support system in management is usage of mathematical and statistical applications. Essentially this software is coding in Visual Basic with algorithms in Visual C++ and using MS-Access data. Libraries have been created as Active X controls. Image handling tool has been one of the main features in order to handle remote sensing data. Tools exist for transformation, enhancement and classification.

Now-a-days the computer learning in school has begun from the primary classes and the teaching of programming with compilers such as Visual C++ and Visual Basic exist as a part of the syllabi of Computer Science in many good schools. So the inclusion of GIS would be of worth right from the school level. It has been pointed out by some of the top administrative authorities that the planners do not tend to use the modern tools and techniques in planning. How will it be possible unless it finds a place at the grass root level? Perhaps some combinations like Geography, Economics and Mathematics/Statistics would be ideal for good management base. Even otherwise, the inclusion of GIS in the course of Geography and Computer Science will change the present status of these subjects sufficiently. Needless to add, that the

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scope will be broadened with all these essential elements. Relevance, importance and urgency of GIS felt by all the academicians at present is a must for prospective courses of both subjects of Geography and Computer Science.

FIRST INDIAN AT THE SOUTH POLE*

P.S. Sehra
Professor of Meteorology Agronomy
Department of Agricultural Meteorology
Punjab Agricultural University
Ludhiana

* Reproduced with permission from Indian Mountaineer, Vol. 2, 1978

Adaptability certificate: Thinking that the Russian doctor on board the ship 'Viese' sailing to Antarctica might be asking for my International Health Certificate, I promptly gave him that. But he smiled and remarked, "Wintering over the South Polar Ice-cap where the temperatures range from 40 to 90°C and the winds blow with speeds exceeding 200-300 km per hour is not a joke, my friend. Your certificate is meant only for the posh cities of the world. Antarctica demands from an individual the utmost in physical stamina and mental soundness with mature judgement so that a man working there may act quickly and positively in order to survive. Prior to selection for Antarctica, we conduct a thorough medical check-up and a tough physiological and psychological screening of our expedition members and also impart them a special training. Only after qualifying all these tests and training they are given 'adaptability certificate' and taken to harshest continent

Fig. 1. : Icebergs floating in the frozen Antarctic Ocean

I did not undergo any special acclimatisation programme or training before setting foot at the South Pole. I had no 'adaptability certificate' and the Soviets (erstwhile USSR) allowed me to participate in their Antarctic Expedition during 1971-73 at my own personal risk. My long Antarctic ordeal included many unforgettable scary moments in the ice.

What is Antarctica? In Greek it means "Anti-Arctic i.e., the opposite of the Arctic". Including its permanently attached ice shelves, Antarctica covers about 5.5 million square miles (14.23 $\times 10^6$ km^2 approximately) surrounding the South Pole, and has 18,500 miles (29,767km) of coastline. It is as big as the United States and Mexico combined. About 95 per cent of the world's permanent ice is in the Antarctic: 7 million cubic miles (30.5 $\times 10^6$ km^3) of it. This great mass has made Antarctica the highest of all continents, its average elevation is about 4,500 feet (225m). The world's lowest temperature minus 88.3°C has been recorded in Antarctica and violent snowstorms with winds of over 250 km per hour speed are very frequent in this icy desert. It is the coldest and the windiest continent.

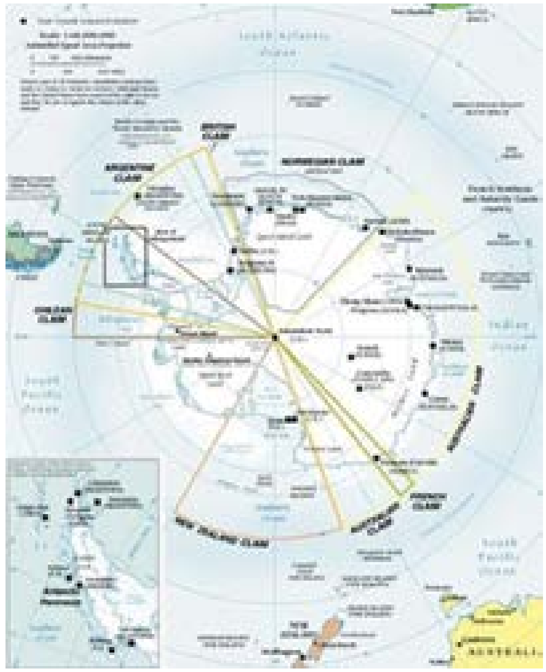

Fig. 2: Map of Antarctica and South Pole

Although there is so much ice in Antarctica, there is almost no fresh water. Such a cold dry area cannot support much life of any kind. On land only 4.5 per cent of which is bare, a few primitive plants exist, and there are bacteria and some insects and similar small animals. The Antarctic waters, however, abound in sea life ranging from microscopic plants, plankton to giant whales. The best-known birds in Antarctica are the flightless penguins, which walk erect and waddle along like a cartoonist's version of man returning from a formal dinner! Wandering through the ice pack, penguins frequently encounter seals, six species of which breed in the Antarctic. There are also colonies of some flying birds such as the polar skuas and snow petrels. To the present knowledge, Antarctica has never had any native human population. Men now go to Antarctica primarily to study the earth, the space around it and the life upon it.

The climax of our Antarctic Expedition came in when we reached the geographic South Pole. I got lost in my deep thoughts while standing at the bottom of the world (90 degrees South) on a high ice-covered plateau more than 9,000 feet (nearly 2,700m) above sea level. The temperature at that time was 60°C and the pressure much below the normal. It was the place first reached by the great Norwegian explorer Roald Amundsen 60 years ago (1911). On January 17, 1912 about a month after Amundsen, Captain Scott and four other Englishmen stood on the same spot, who were later trapped by a blizzard and never returned home.

At this historical place there is an American station called Amundsen-Scott South Pole Station, which has been in operation since 1957, the International Geophysical Year. The sun sets here for the winter on March 22, not to rise again until September 21. A full year consists of only one day and one night, each of six months duration. On June 21, the sun begins its ascent marking Midwinter Day. As at all stations this turning point of the winter was celebrated with gusto. With the day marked by holiday routine, practically every one of us slept late. The only exception was our cook, who was busy preparing a lavish meal for that evening.

Now a desperate struggle of two months to reach 'Vostok' the pole of inaccessibility and extreme cold (having recorded the world's lowest temperature (minus 88.3°C). During our 1,500 km trekking from Mirny station to Vostok located at the geomagnetic South Pole, we had plenty of difficulties, we sometimes failed, we sometimes won, we always faced them and made all possible scientific observations.

Fig. 3: Glaciological and Geodetic observations being made on way to Vostok. The author participated in the 1,500 km sledge odyssey from Mirni to Vostok, the pole of cold, completed in one and a half month

Our trekking expedition comprising of heavy machines 'towmobiles' and dog sledges carrying about 30 tons of equipment for Vostok roared into action and slowly pulled out of Mirny during the summer. After two weeks, a heavy snowstorm began reducing the visibility to zero. Most of the route was 3,000 metres above sea level with constantly low temperatures, about minus 70°C due to which our snow tractors could not move. Many of our huskies pulling our sledges died on the way and we had to eat their meat in order to survive. Snowstorms and poor visibility continued to hinder our progress. One of our comrades who became ill with acute appendicitis died on the way and yet another fell into a deep crevasse and buried alive. Despite all these difficulties, we traversed 1,500 kilometres in two months, and conquered the pole of inaccessibility. I can forget anything in my life but not these tough experiences. I must add here that one who has not travelled deep into the South Pole Ice-Cap cannot know Antarctica!

The coldest place in the world 'Vostok', at 78.45 degrees South and 106.8 degrees East, lies at an altitude of 3,488 metres on approximately 3,700 metres of ice. The air is perpetually drier then in the world's worst deserts. During the polar night, temperatures drop so low that they would normally freeze carbon dioxide out of the atmosphere which condenses at 78.5°C. The high altitude starves lungs of oxygen, and the normal rate of heartbeats nearly doubles. Here 15 of us wintered over, isolated from contact with rest of the world for more than nine months, half of this time in utter darkness. I must say that six months continuous darkness followed by six months daylight at the South Pole were the extremely boring phenomena of nature I experienced there. When I returned, I found that a 12 hour day followed by a 12 hour night were, indeed a great blessing!

Fig. 4: A view of the Soviet Antarctic station 'Molodezhnaya'. During the extremely cold, dark and stormy 6-month long night, some of the huts were blown off along with the inmates. Winters are harsh and there is plenty of snow accumulation due to violent snow-storms. Some huts are built underground wherein sound does not reach, nor does light filter through.

During our 1500 km sledge odyssey between Mirny and Vostok, we made snow measuring observations and set up new automatic stations for the continuous recording of magnetic variations and meteorological data in addition to our other field work on geodesy, glaciology and so on.

Circumnavigating all around the Antarctic continent on board the icebreaker ships 'Navarin' and 'Ob' during the expedition, was most thrilling voyage of my life which recalls me of Captain James Cook who between 1772 to 1775 first sailed around Antarctic and brought to an end the dream of an inhabited southern continent.

During the Antarctic circumnavigation our ships resupplied all the Soviet coastal stations viz., Mirny, Leningradskaya, Bellingshausen, Novolazarevskaya, Amery and Molodezhnaya and relieved the old staff with the new expedition members. We sailed all along the Antarctic Circle and chose the site of a new Soviet station 'Russkaya' on the shore of the Amundsen Sea. We took fuel and fresh food provisions for our ships and for the Antarctic stations from the port of Punta Arenas, Chile. But, unfortunately, the station Molodezhnaya could not be given sufficient food supply due to which we had to face a number of problems there. I visited several other stations operated by the Antarctic Treaty member-nations in order to collect maximum

possible scientific data.

Fig. 5: 'M-100' rocket at take-off from the launching-pad near 'Molodezhnaya' Antarctic station during the extremely cold, dark and stormy 6-month long South Polar night

Fig. 6: About 95 per cent of the world's permanent ice is in the Antarctic 7 million cubic miles (1 cubic mile is nearly 4.1 cubic kilometre) of ice. Large pieces of ice called icebergs break off from the ice-shelves and ice glaciers and float away from the coast. The author and Comrade Merculov resting in the Ice of an ice-berg.

I worked for more than a year at the station 'Molodezhnaya' which is the continental headquarters for the Soviet Antarctic Expeditions. During the harsh winter, an emergency was declared at our station due to the acute shortage of foodstuff and other essential provisions. Both the quality and quantity of food were utterly poor. Our tinned food also got exhausted during the extremely cold and stormy polar night. As a consequence, we had to live on the Antarctic seals, penguins and fish. I still remember my days in Antarctica when we also had to eat the meat of our favourite huskies in order to survive. Smokers at the station were often found searching for the used cigarette butts. When the 'Vodka' was also finished, many of us started drinking pure spirit mixed with tea-water, Antarctic whisky!

Besides this, we faced innumerable number of other difficulties while wintering in Antarctica. Comrade Evanov developed appendicitis trouble

and had to be operated. Two of our expedition

members became mentally ill due to long isolation and had to be closed indoors. During the winter, we encountered several violent blizzards with speeds exceeding 200 km per hour. Some of our houses were blown off along with the inmates and our unfortunate comrades died for the cause of science.

Rebirth! yes, in a way I was reborn when I fell into a deep crevasse in Antarctica on 14th March,

Fig. 9: The author in the company of penguins. The penguins are very curious and social birds and frequently come close to camps, ships and groups of men to watch what is going on. They usually walk erect and waddle along looking like a cartoonist's version of man returning from a formal dinner.

1972. I was hardly an inch away from my death when I was pulled out of the 'death pit' with long ropes by a timely rescue party. In another accident I fell down from a 200 metre ridge due to a helpless blind-walk in a violent snowstorm and lost few teeth and suffered a fracture in my legs. In November 1972, I undertook an independent trekking to a distant iceberg which was about 150 km far and named it as 'Indian Elephant Ice berg'. On the return from there, misfortune followed my footsteps. Growing weaker each day from the exertion and the lack of food, I also encountered violent storms and blizzards and lost the way. I met with several hair raising accidents during my South Pole odyssey, but fortune ever smiled on me and I always had a narrow escape.

Fig. 7: A heavy 'towmobile' machine, a sort of snow-tank which is the latest mode of transportation in Antarctica

Fig. 8: The seas surrounding the Antarctic continent freeze during winter months for hundred of miles offshore. In summer the ice breaks up to form pack-ice which constitutes a hazard to shipping and a barrier, making access to the coast extremely difficult. For these reasons special ice-breaker ships are used.

In Antarctica, I was the Project Scientist for carrying out the upper atmospheric rocket soundings from the main Soviet Station Molodezhnaya. The M-100 rockets could carry 67 kg payload upto 100 km altitude and were launched twice in a week. My research and investigations showed for the first time that sizable perturbations occur in the South Polar atmospheric structure during the winter.

My participation in the Soviet Antarctic Expedition in 1971-73 was made possible (through the efforts of Prof. P.D. Bhavsar. Prof, P.R. Pisharoty and the late Prof. Vikram A. Sarabhai) under an agreement between the Indian Space Research Organisation and the Hydrometeorological Service of the USSR.

Editor's Note

India is amongst few countries of the world that has been actively pursuing programmes to conduct wide ranging studies on Antarctica. It has already established a permanent station on this icy continent. The first Indian expedition to Antarctic Programme was undertaken in 1981. Since then India has been sending multi-disciplinary scientific expeditions to Antarctica every year. In 1983 India commissioned its first research station in Antarctica, which was named as 'Dakshin Gangotri'. It has since been replaced by the indigenously designed second Indian permanent station, 'Maitri' with adequate infrastructure facilities for conducting scientific research of contemporary nature in the icy continent. India has always recognised the importance of preserving the pristine nature of this remote and unique continent. To uphold this commitment, India, an original votary of the Protocol on Environmental Protection to the Antarctic Treaty, has ratified this Protocol in April, 1996.

WHY CAMERA LENSES APPEAR COLOURED ?

B.K. Sharma

Department of Education in Science and Mathematics
National Council of Educational Research and Training, New Delhi

The optical components, such as lenses, prisms and mirrors of a large variety of optical instruments (e.g. still/movie or TV cameras, binoculars, telescopes, microscopes, etc.) make use of the laws of reflection and refraction of light. The purpose of each of such instrument is to form as true an image as possible of the object. When a beam of light is incident on the boundary or interface between two media of different refractive indices (e.g. a glass plate/lens or a prism placed in air/liquid), a part of the light energy is transmitted, a part is absorbed and the remaining part is reflected from the surface. The transmitted or reflected light may form an image of the object if the light rays actually meet after transmission or reflection. The resulting image is often not distinct, on account of the stray light accompanying the transmitted or reflected light due to surface reflections.

The quality of a camera basically depends on ability of its lens system to transmit light through the glass. This ability depends on the surface area of the lens facing the object. In case of high quality movie or TV cameras, the optical system consists of multi-element lens system (a combination of several lenses), the light due to reflection from each of the refracting surfaces, reduces greatly the net transmission of light energy through it. In addition to lower transmission of light energy, the lens suffers from another drawback due to the surface reflections. The light reflected at the various surfaces may reach the focal plane of the camera in a random way here it gives rise to a 'ghost image', thereby reducing the contrast of the final image. In order to obtain a sharp picture/image, it is essential to reduce, by some means intensity losses due to the surface reflection of the camera lens.

Bloomed Lenses

Most of us might have noticed that the lenses of cameras, binoculars and other such high quality optical instruments appear to be coloured. The coloured appearance may vary from purple to blue-violet or even sometimes black, depending on the type and quality of optical system. Many of us might have wondered why the lenses made of transparent glasses should look coloured.

The coloured appearance of the lenses is due to thin film coatings on optical components (such as photographic camera lenses or microscope/ telescope objectives) to reduce/minimize loss of light due to reflection from the glass surface. Such a treatment by coating the surfaces of lenses with extremely thin films of a transparent material is highly effective in eliminating stray reflection of light and thereby increasing the contrast of the image formed by highly corrected lenses having a large number of air-glass surfaces. Such thin film optical coatings are called anti-reflection or non-reflective coatings. However, such non-reflective coatings destroy no light. There is no violation of the principle of conservation of energy in this process rather there is a redistribution of energy in manner that reduction in the reflected light intensity results in the enhancement in the intensity of transmitted light thus, these coating reduce surface reflection losses and improve efficiency of the lenses. The camera lenses look coloured because thin, transparent coatings of appropriate, durable material are applied on their surface. Such a coated lens appears as a 'ripe plum colour bloom' and so the lens is sometimes called 'bloomed' lens. It is for this reason that the camera lenses provided with such anti-reflection or non-reflective coatings are more popularly described as 'coated lens' or 'bloomed lens'.

Historical Background

The optical effects exhibited by thin films started playing key role, after having been motivated by the observations made by Fraunhoffer (1817) of enhanced transmission through the tarnished or tainted surface of a lens. Lord Rayleigh (1888) independently reported the lowering or reflectance from a tarnished plate made of crown glass and related it to the formation of a thin layer of refractive index different from that of the glass. H.D. Taylor (1891) also found that objects looked brighter through a tarnished telescope lens compared to that of a new one. Subsequently, Tayloe (1904) and Kollmorgen (1916) developed a chemical technique for artificially tarnishing a lens. Also G. Bauer (1934) showed that a thin transparent film coating on glass is able to increase the transmission of light energy, due to the interference of light reflected from the front and back surfaces of the film. With the development of such simple coatings called anti-reflection coatings and other thin film devices, a new field in optics, called 'thin film optics' came into existence and since then, tremendous developments in the field has taken place.

The optical coatings, in general, consist of dielectric layers stacked in the manner required by the design characteristics for a desired function. Such stacks may consist of single layer or multi-layer coatings. The effect produced by optical coatings is based on the phenomenon of interference of light. A beam of light entering the system of optical coatings suffers multiple internal reflections and the fractions of the incident beam that emerge as transmitted or reflected beam at the boundary of two media, acquire certain characteristics which are representative properties of the design pattern of the thin film stack. The simplest of such a design is a single layer of dielectric coating called the anti-reflection coating of single layer. Normally, the film thickness corresponds to 550 nm wavelength, in the yellow-green region of the visible spectrum, since the human eye is most sensitive for this wavelength. However, anti-reflection effects can be produced for any other wavelength by suitable controlling the thickness of the dielectric layers. The multi-layer system of anti-reflection coatings consisting of a stack of suitable high refractive index and low refractive index material of appropriate thickness, necessary to achieve better efficiency, having almost zero reflections over a wide wavelength range, has also been developed. The specific example of the anti-reflection coatings may be a pile of several glass plates (say 5 to 7) coated with the anti-reflection layer or film at the central portion of each surface. If such a 'coated pile of glass plates' is placed over any printed matter, the visibility of the printed matter through the coated portion of the glass gets considerably improved. The coated portion shows better legibility as compared to that through the uncoated portion because the transmission of light energy through the uncoated portion of the pile of glass plates is only about 60% or so.

Principle of Optical Coatings

The basic principle involved in the working of optical coatings is the phenomenon of interference of light. The phenomenon of redistribution of light energy due to superposition of two coherent light waves while travelling along the same direction in a medium is called interference. Due to superposition of waves from two such sources, at some points in a medium, the intensity of light is maximum at some points, depending on the optical path difference between them. The phenomenon of interference of light provides conclusive evidence that light behaves like wave rather than a stream of particles (as was believed by Newton). Light waves are electromagnetic waves and are transverse in nature. The light waves can even travel in vacuum with a speed, C, of 3×10^8 m/s and with a reduced speed v (=c/n) in an optically denser medium of refractive index n. The refractive index, n, of a medium varies with the wavelength λ of the light wave throughout the visible region (about 390 nm to 760 nm) in accordance with Cauchy's formula phase change of 180° or π rad $(n = A + B/\lambda^2 + C/\lambda^4 + ...$ The amount of bending of light wave at the interface of two media also varies with wavelength, giving rise to dispersion effects, such as that observed in case of a glass prism producing spectrum with white light.

When a light wave is incident on an interface separating two media (such as air and glass) and travels from an optically less dense medium (air) towards an optically more dense medium (such as a glass plate/lens), the reflected light wave undergoes a phase change of 180^0 or π rad. This rule is sometimes remembered using the phrase 'lows to high, a change of 'Pi'. When reflection occurs from an optically less dense medium (such as light incident from glass to air), the reflected light wave does not undergo such a phase change at the glass air interface. However, the transmitted light wave does not experience an additional phase change in either case.

Optical Interface Reflectance and Transmittance

The fraction of the light wave reflected from the interface separating two media increases with the angle or incidence and is determined by the refractive indices n_1 and n_2 of the two media. At grazing incidence (at angles of incidence, θ_1 nearly 90°), the surface becomes an excellent reflector. A common example of this effect is the high reflecting power of a wet road when light from automobile headlights strikes the road with a grazing incidence. Even a clear window glass makes a reasonably good mirror when light strikes at a grazing angle. The fraction of the reflected light energy i.e., reflectance (or reflectivity) $R = I_r / I_0$) of an interface as a measure of the ratio of reflected irradiance I_r (or intensity proportional to the square of the amplitude of the reflected wave) to the incident irradiance/intensity I_0 and also the fraction of transmitted light energy i.e., transmittance (or transimitivity) T= (I_t / I_0) as a measure of the ratio of transmitted irradiance I_t (or intensity) to the incident irradiance I_0, are both determined by the refractive indices n_1, n_2 of the two media and the angle of incidence θ_1. The fraction (I_r/I_0) and (I_t/I_0) for glass (n=1.50) and air (n=1.00) for different values of angle of incidence at the air-glass interface for external reflection and internal reflection are shown in Fig.1(a) and 1(b) respectively. It may be observed that for angles less than the critical angle 41.8° (for a[illegible]s system) including normal incidence ($\theta_1 = 0^0$), part of the incident light energy is transmitted (Fig. 1a) an dpart is reflected (Fig.1b). As the critical angle ($\theta_1 = 41.8^0$) is approached, the transmitted fraction falls continuously to zero as shown in Fig. (1b) and for $\theta_1 \geq 41.8^0$ all the light energy is reflected.

The equations that describe the reflection and transmission of light at the boundary between two media are known as Fresnel's equations. These can be obtained by applying boundary conditions that require the continuity of the components of certain electric and magnetic fields associated with the propagation of light wave as an electromagnetic wave at the interface between two dielectric media.

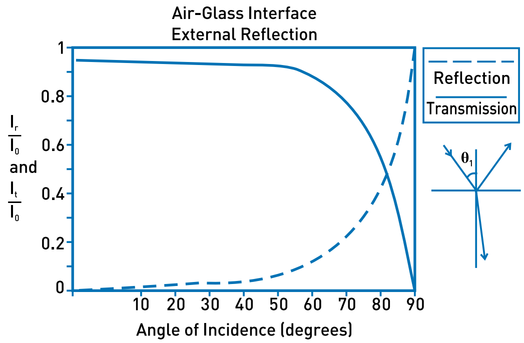

Fig. 1 (a)

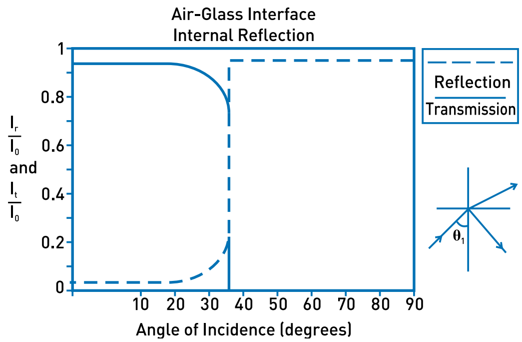

Fig. 1 (b)

Fig. 1(a) and (b) The fraction of light energy that is reflected at the boundary between the two dielectric depends on the angle of incidence. I_t and I_r are the transmitted and relected irradiances, respectively, and I_i is the incident irradiance. The fraction calculated here are for glass (n = 1.50) and air (n = 1.00)

Assuming absorption losses at the interface as negligible, the expressions for the reflectance — R(θ_1) and the transmittance T()at the interface can be expresses in terms of the refractive indices n_1, n_2 of the two media and the angle of incidence as (1,2)

$$R(\theta_1) = \frac{1}{2}\left[(n_1\cos\theta_1 - n_2\cos\theta_2)^2/(n_1\cos\theta_1 + n_2\cos\theta_2)^2 + (n_2\cos\theta_1 - n_1\cos\theta_2)^2/(n_2\cos\theta_1 + n_1\cos\theta_2)^2\right]$$

$$= \frac{1}{2}\sin^2(q_1 \square q_2)/\sin^2(q_1+q_2) + \tan^2(\theta_1-\theta_2)/\tan^2(\theta_1+\theta_2)$$

O r

$$R(\theta_1) = \frac{1}{2}\Big[\{(n_1\cos\theta_1 - \sqrt{(n_2^2 - n_1^2 - \sin^2\theta_1)}\}^2 / \{(n_1\cos\theta_1 + \sqrt{(n_2^2 - n_1^2 - \sin^2\theta_1)}\}^2$$

$$+ \{(n_2\cos\theta_1 - (n_1/n_2)\sqrt{(n_2^2 - n_1^2\sin^2\theta_1)}\}/ (n_2\cos\theta_1 + (n_1/n_2)\sqrt{(n_2^2 - n_1^2\sin^2\theta_1)})^2\Big] \ldots (1)$$

$$T(\theta_1) = \frac{1}{2}\{(4n_1n_2\cos\theta_1\cos\theta_2)/(n_1\cos\theta_1 + n_2\cos\theta_2)^2 + 4n_1n_2\cos\theta_1\cos\theta_2/(n_2\cos\theta_1 + n_1\cos\theta_2)^2\}$$

$$- \frac{1}{2}\Big[\{(4n_1\cos\theta_1\sqrt{(n_2^2 - n_1^2 - \sin^2\theta_1)})\}/\{(n_1\cos\theta_1 + \sqrt{(n_2^2 - n_1^2\sin^2\theta_1)})\}^2 +$$

$$\{(4n_1\cos\theta_1\sqrt{(n_2^2 - n_1^2 - \sin^2\theta_1)})/(n_2\cos\theta_1 + (n_1/n_2)\sqrt{(n_2^2 - n_1^2\sin^2\theta_1)})\}^2\Big] \ldots (2)$$

where the transmitted light wave making an angle of refraction θ_2 with the interface normal follows the Snell's law of refraction as $n_1\cos\theta_1 = n_2\cos\theta_2$.

For normal incidence $\theta_1 = 0^\circ$ in either direction, equations (1) and (2) for the reflectance R and transmittance T reduce to

$$R = I_r/I_0 = \{(n_2 - n_1)/(n_2 + n_1)\}^2 \ldots (1a)$$

$$T = I_t/I_0 = \{(4n_1n_2)/(n_2 + n_1)^2\} \ldots (2a).$$

Equations (1a) and (2a) may be employed to calculate the reflectance and transmittance of the interface separating two transparent media. It is interesting to note that for normal incidence, about 4% of the incident light is reflected at each interface or air-glass surface (n_1=1.00 and n_2= 1.50) of the eye glass/lens or a glass plate. Similarly, about 4.3% and 6% of the incident light is reflected at each interface or air-crown glass surface (n_1=1.00 and n_2= 1.52) and air-flint glass surface (n_1=1.00 and n_2= 1.65) respectively. Since the eyeglass or glass plate or lens has two boundaries the total amount of reflected light is about 8% of the incident light. Assuming that there is no absorption by glass, only 92% of the incident light energy striking the front surface of the eye glass/lenses is transmitted through the eye glass/lens and making it to the eyes.

The efficiency of a camera depend primarily on the transmittance of the lens. For a multi-element lens system having z glass-air boundaries (or interfaces), the transmittance can be expressed as

$$T = (1-R_1)\ (1-R_2)\ (1-R_3)\ldots\ldots(1-R_z)\ldots\ldots(3).$$

For a simple, single lens camera, despite its seemingly insignificance, this 8% reflectance (for the two surfaces of the lens, each contributing 4% reflectance) may actually seriously degrade the performance of the optical systems in two ways:

(i) When a large number of surface is involved, the transmission loss may be significant. For example, with a 4% reflectance at each glass-air surface, the net transmission is about 44.2% for a multi-element camera lens system (e.g. a typical 11 element camera lens) with 20 glass-air surfaces.

(ii) When the reflected light may also show up in undesirable places as a general haze or in the form of 'ghost images', thereby reducing the contrast of the image.

These major problems can be minimised or eliminated with the help of the anti-reflection coatings. As the reflectance R in equation (1a) is quadratic in the difference between the refractive index, the total reflectance may be reduced by interposing between the original two media a very thin film or layer of appropriate transparent material with an intermediate refractive index.

Anti-reflection Coatings

The unwanted reflections from the surface of glass lens or plate can be suppressed (at a chosen wavelength) by coating the glass surface of optional components with an appropriate material coating or film having suitable refractive index and of proper thickness. The performance of such thin film in anti-reflection coatings can be understood in a qualitative way by considering a parallel beam of light of incident intensity I_0, incident on the upper surface of the glass lens/plate of refractive index n_3 coated on one side with transparent thin film of thickness t and refractive index n_2, placed in air of refractive index n_1 (=1.00) as shown in Fig.2.

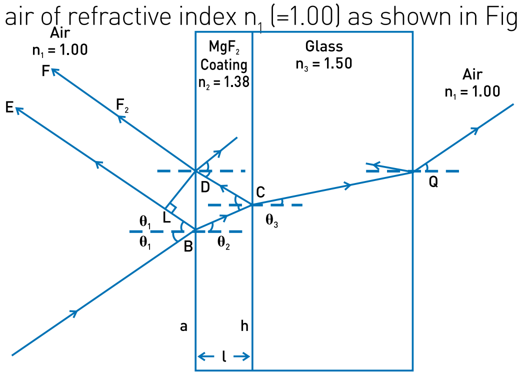

Fig. 2

In order to reduce reflectivity R, a material of appropriate thickness t and suitable refractive index n_2, chosen at some value ($n_1 < n_2 < n_3$) is deposited on the transparent substrate (glass). Then equal quantities of light will be reflected from the film's outer surface b (air-film boundary) and the film-glass boundary surface a, when a ray AB in incident, on the boundary of the air-film surface, making an angle θ_1 with the normal to it. At the interface a, it is partly reflected along BE as a ray r_1 from the upper surface of the film and is partly refracted along BC into the film with an angle of refraction θ_2 such that

$$\sin\theta_2 = (n_1/n_2)\sin\theta_1$$

At the point C, on the lower surface b of the film (or the film-glass interface b), the ray BC is again partly reflected firstly along CD, traversing as a ray r_2, and partly transmitted into the glass with angle of refraction θ_3 such that

$$\sin\theta_3 = (n_2/n_3)\sin\theta_2$$

and finally emerges out into the air. This emergent ray is parallel to the incident ray as the two surfaces of the film and the glass plate are parallel.

The incident beam thus gets divided at B into two beams of different amplitudes, out of which the refracted beam suffers multiple reflections and refractions at the interfaces a and b. The amplitudes of the reflected beams r_1 and r_2 from the air-film interface a and the film-glass interface b are nearly equal in magnitude but opposite in phase and hence these interfere destructively, depending on the optical path difference between them.

The optical path difference $\Delta = n_2(BC + CD) - n_1$ between reflected rays r_1 and r_2 is evidently

$$2n_2 t\cos\theta_1 = 2t\sqrt{(n_2^2 - n_1^2 - \sin^2\theta_1)}$$

and the phase difference λ between them $\Delta\theta$ between them = $(2\pi/\lambda) \times$ optical path difference

$$\Delta x = (2\pi/\lambda) \times 2t(n_2^2 - n_1^2 \sin^2\theta_1)^{1/2} \quad ....(4)$$

In case of a non-reflecting film, the light moves into a medium in which the velocity is less (denser medium) at each of the two reflecting surfaces, hence there is no resultant phase change due to reflection. By a judicious choice of the film thickness, we may easily establish destructive interference (and minimize the effect of reflection) between the light reflected at the lower and upper surfaces of the film for certain wavelength.

Quarter-waves Non-reflecting Film Thickness–A Necessity for Destructive Interference

Destructive interference occurs between the reflected rays r_1 and r_2, resulting in the minimum intensity, when optical path difference Dx between interfering beams is an odd multiple of half wavelength i.e., $(m+1/2)\lambda$, with integer m=0, ± 1, ± 2, ± 3,........, or phase difference D between them is $(2m+1)\pi$, being odd multiple of π. Thus, the condition for destructive interference in this case, using Eq.(4), is

$$2n_2 t\cos\theta_2 = 2t\sqrt{(n_2^2 - n_1^2\theta_1)} = (m + 1/2)\lambda \quad ...(5)$$

It may be noted that an additional, same phase change of π rad or 180°, on reflection, is associated with each interfering ray for reflection at both the upper and lower surface of the film coating. This is because the reflection is from the denser medium both at the air-film interface a and also at the film glass interface b. Since the same additional phase change occurs in each reflection, there is not net change in phase after the two reflections. This implies that Eq.(5) would be valid in this case as we seek destructive interference between the two rays i.e., r_1 and r_2 minimal reflection for a non-reflecting film coating so that maximum energy passes into the glass.

For normal incidence, the optical path difference for destructive inference, using eq.(5), leads to the expression

$$2n_2 t = \lambda/2 \quad ...(6)$$

Thus, maximum destructive interference occurs when the optical path lengths of the interfering beams r_1 and r_2 differ by half-wavelength. Consequently, no light is reflected and the film appears dark by reflected light. It follows from Eq. (6) that if the minimum film thickness $t = \lambda/4n_2$ is one-quarter wavelength for normal incidence, then the light reflected from the first boundary surface a (i.e. air-film interface), will be 180° out of phase with that reflected from the second boundary surface b (i.e., film-glass interface) and complete destructive interference will result. The minimum layer-thickness can be one-quarter wavelength for any given wave length.

Choice of Film Coating Material for Minimal Reflection

The minimal reflection (i.e., total cancellation of zero reflected intensity) can occur if the two reflected beams have the same intensity. Thus the condition for the reflectance R (or reflectivity) of a transparent material ensures that the reflected beams r_1 and r_2 have equal amplitudes/intensities, using Eq. (la) for normal incidence, can be written as

R (air-film) = R (film-glass)

Such that,

$\{(n_2 - n_1) / (n_2 + n_1)\}^2 = \{(n_3 - n_2) / (n_3 + n_2)\}^3$ ...(7)

Eg. (7) leads to the relationship amongst the refractive indices n_1, n_2 and n_3 as

$n_2 = (n_1 n_3)^{1/2}$ ...(8)

It follows from Eqs. (6) and (8) that the intensities of the two reflected beams are equal, when the refractive Index n_2 of the coated film/layer, of one- quarter wavelength thickness, for the normal incidence, is the geometric mean between those of the two media (i.e., glass and air). Consequently, the reflection will be divided equally between the two surfaces and complete destructive interference and minimum reflection would result.

This implies that a thin film of refractive index n_2, that is equivalent to the square root of the refractive index n_3 of glass (n_1 for air is 1.00), and of quarter wave optical thickness reduces the surface reflectance R of the glass to zero for a particular wavelength, say λ_0. This is usually chosen in the yellow-green region (λ_0 = 550 nm) of the visible spectrum for which the human eye is most sensitive. Ordinary window glass (n_3 = 1.50) can be rendered non-reflecting for yellow-green light (λ = 550 nm) by anti-reflection coating on glass with a thin film material of refractive index $n_2 = (n_2)^{1/2}$ = 1.225 and minimum film thickness $t = \lambda / 4n_2$ = 112 nm. In practice, suitable transparent, thin film material (solid substance) having a refractive index of 1.225 which satisfies the condition $n_2 = (n_1 n_3)^{1/2}$ with necessary harness are not available. A transparent and durable material such as magnesium fluoride (MgF_2) which has a refractive index of 1.38, close to this value, at wavelength λ = 550 nm in generally used as a compromise and can be readily deposited on the glass surface. In its natural form, it is called cryolite.

The reflectance of glass coated with a quarter wave thick film of MgF_2 having optional thickness of 100 nm at λ = 550 nm is reduced from about 4% to about 1% which is one-fourth that of uncoated glass. This can result in a considerable reduction in loss of light in the case of optical instruments. By using more layers, further reduction in reflectance or reflective intensity may be obtained, although the process is difficult and expensive. Fig. 3 shows how the significant reduction occurs in reflectance using two layers or three layers on glass lenses, in addition to single layer coatings. With such a single layer anti-reflection coating on all surfaces of the typical 11 element camera lens with 20 glass-air interfaces, the transmitivity increases from about 44.2% to 86%, for yellow-green light of the visible spectrum. Some reflection then takes place at both longer and shorter wavelengths and the reflected light has a purple hue.

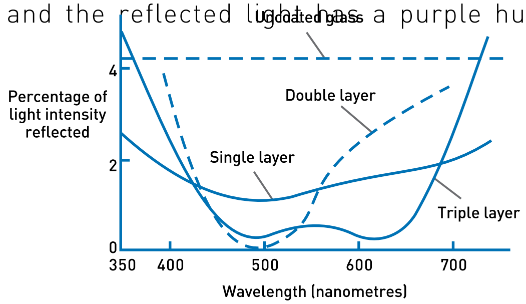

Fig. 3. Percentage of light intensity reflected by glass with one, two or three coating layers.

'Bloom' coloured Appearance of Camera Lenses

A glass lens (or a plate) coated with anti-reflection film looks bluish red (or purple) because the reflected light has predominantly blue and red components of visible white light. A single coating on a lens reduces the reflected light intensity to varying degrees throughout the visible spectral range of wavelengths. Such lenses specially designed for the camera are least reflective for a particular wavelength, usually for yellow-green light. They reflect more red and blue/violet light (at both longer and shorter wavelengths) which gives the camera lens a purplish red appearance. Thus the colour of the coating seen in the reflected light is (white minus green) magenta (i.e., a combination of red and blue light). This is the purplish red colour, which give the 'bloom' to the camera lenses.

More efficient anti-reflection coatings which give zero reflectance at a single wavelength or minimum reflectance over a wide range of wavelength region, can be designed by using multilayer anti-reflection coatings. However, the type of the anti-reflection coating in any desired, particular application will depend on a variety of factors including the type of the glass, the wavelength range, required performance and the cost factor. For example, binocular lenses and camera lenses, used in black and white photography, which have a few elements, need only single layer anti-reflection coatings. In cameras or other optical systems where monochromatic, coherent light such as Laser beam is used, two-layer anti-reflection coatings are ideally suitable which give zero reflectance at the required particular wavelength chosen for the purpose. However, in cameras used for true colour reproduction and those consisting of many element lenses, such as high quality camera lens that may have as many as 11 components or so, the lens surfaces should have at least three or more, multi-layer anti-reflection coatings to minimise the reflectance throughout the visible region. Glass lenses with this type of multi-layer coatings reflect very little or practically no light in the visible region and appear black.

Thus, by using two layers, one of higher refractive index and other of lower one, it is possible to obtain zero reflectance at one wavelength with available coating materials for anti-reflection coatings. More layers obviously afford greater latitude and more extensive possibilities. Therefore, with three suitably chosen layers, the reflectance can be reduced to zero for two wavelengths and can even be made to average less than (1/4%) over almost entire visible spectrum as shown in Fig. 3. In general, by increasing the number of layers, more efficient anti-reflection coatings can be designed. Alternately, the design performance of a few layer designs can be further improved. However, in practice, it is necessary to keep the number of layers to the minimum, on cost factor considerations and more particularly to avoid the possibility of errors and defects occurring in the coating process. Moreover, it may be remembered that the fewer the number of film coatings, the better is the optical performance of the anti-reflections coatings even at greater angles of incidence. When many element lenses coated surfaces are used, spectral variation of reflectance may significantly affect the character of the transmitted light. For example, spectral transmittance of 32 surfaces (3) of extra dense glass EDF-3(n=1.72) coated with MgF_2 anti-reflection film shows a transmittance of about 47% at 400nm, maximum peak transmittance of about 94% at 540 nm and then transmittance decreasing to about 64% at 700nm.

How to make Anti-reflection Coatings

The most versatile method of depositing the thin film anti-reflection coatings is the vacuum evaporation process. Almost all optical components of high-quality instruments are now coated with such films on the glass surfaces. It may be interesting to know how these thin films are deposited on the glass with only a brief description of making a single layer MgF_2 anti-reflection coatings, which are usually used for most camera lenses. These anti-reflection film coatings are deposited by evaporating magnesium fluoride on glass lenses in vacuum. The proper thickness depends on the time of exposure for 'the part to' these vapours. Clean glass lenses/components required to be coated are mounted on a spherical work holder. MgF_2 is put in a small molybdenum-boat and in mounted in between two electrodes provided on the base plate of the chamber. The chamber is evacuated to a high vacuum of the order of 10^{-5} mm of Hg and the material in the boat is heated to a very high temperature by passing high current through it (by resistance heating method). At high temperatures, MgF_2 evaporates and the vapours condense on the lens surfaces as thin film. While vaccum evaporation process is in progress, one of the glass surfaces is visually monitored for its reflected colour. The vacuum deposition process is continued till the coated glass starts showing the characteristic 'plum, purplish red colour' which corresponds to an optical thickness of a particular quarter-wavelength.

It may be mentioned that in various types of optical coatings the uniformity of deposit, with regard to thickness and structure, and accurate control of thickness amounting to integral multiples of quarter wavelength poses severe experimental difficulties. The uniformity of thickness and structure of optical coatings can be carried out by providing planetary rotation of the transparent substrates (glass surfaces) during the vacuum deposition process, wherein the rotation of each substrate about its own axis averages out the effect of varying angle of incidence. However, the rotation of all the substrates around the source averages out undesirable structural effects arising due to eccentric heating and non-circular shape of the evaporation source.

The thickness of the dielectric layers of appropriate transparent, durable substance is controlled by optical interference method. During the vacuum deposition process, a narrow beam of white light is allowed to be incident on monitor glass lens/plate on which the film is being deposited. The reflected and transmitted beam is then received on a photomultipliers tube after passing through an interference filter of the desired wavelength, usually for yellow-green colour of the visible spectrum, for which the optical coating is required. The intensities of the reflected or transmitted beams are complementary to each other due to interference effects, and the output of the photomultiplier tube shows intensity maxima or minima, corresponding to quarter-wave thicknesses. In order to make the optical method more efficient the incident monitor beam is chopped off at an appropriate frequency which eliminates stray light effects, especially that emitted from the vaporizing source material having been deposited in the form of thin film on the glass during vacuum deposition process.

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