Sunderstanding

International Year of Astronomy 2009

A TERRA SUN OBSERVATORY IN EVERY SCHOOL

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Equipment which can be made in every school by everyone

- Magic mirror kit
- Ball and mirror solar telescope
- Darkroom or portable darkroom
- Ball mount with Angle dangle meter
- Simple telescope with ball mount and stand
- Very Long Focal Length lens
- Moon-Earth -Sun triangle model

Equipment everyone can make

- Geosynchron
- Universal Time Reckoner
- Sundual

Everyone a scientist ?

- Would you too like to become a scientist, like Galileo, or Archimedes, like Aryabhata, Marie Curie or C.V.Raman ? Like Einstein?
- How does one become a scientist ?

- You cannot become a scientist by
  - mugging up books on General Knowledge for taking part in quiz competitions.
  - learning lessons by heart and getting good marks in examinations.

- You can't become a scientist until you learn to understand things thoroughly for yourself.

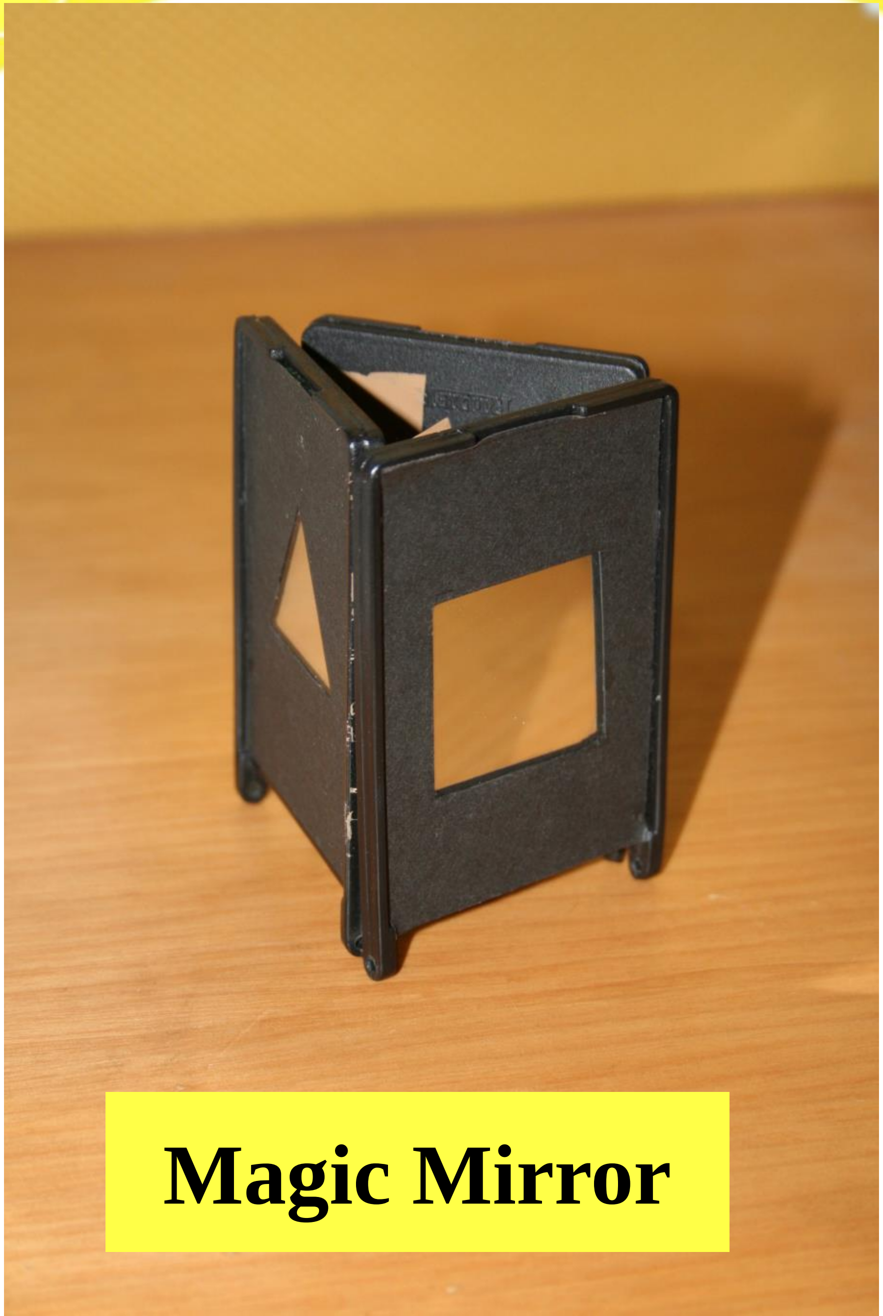
- What is most important is to experiment, to ask questions that nobody has asked before , keeping at it till you find a satisfactory answer.

- Doing experiments, asking questions and finding out the answers for yourself is the only way to do good science.
- So in the following, we are going to suggest some important experiments that you can do yourself.
- These experiments can be done with simple apparatus that you can make yourself.
- But the questions that these experiments give rise to may not be so simple . By trying to answer these questions, you will train yourself to become a good scientist.

- Experiment : The Earth is round.
  - Experiments on a tall building at a beach, at sunrise or sunset.
  - The Sun rises and sets earlier in the east than in the west.

Equipment : The Magic Mirrors

- We take three small rectangular pocket mirrors Make three card rectangles which cover the mirrored glass exactly. In one card rectangle cut a hole which is circular in shape. The diameter of the circle should be around 3 cm. In the second card cut a hole in the shape of a square of side 3 cm. In the third card, the hole should be in the shape of an equilateral triangle of side three cm.
- Paste these three masks on the three mirrors. So now we have three mirrors in the shape of a circle, square and triangle.



Magic Mirror

Experiment: The magic shape transform

- Go out in the sunlight and using the circular mirror cast a reflection of the sun onto the shirt of a friend who is standing one meter away from you. What is the shape of the light figure which forms on his shirt ?
- Repeat the experiment with the square mirror and the triangle mirror. What is the shape of the light reflection on your friend's shirt ?
- Now throw the reflection of the circular mirror on a distant white wall.(which is about 20 metres away) What is the shape of the reflection ?
- Repeat the experiment with the square and the triangle mirror, throwing their reflection on the distant wall. What do you observe ?

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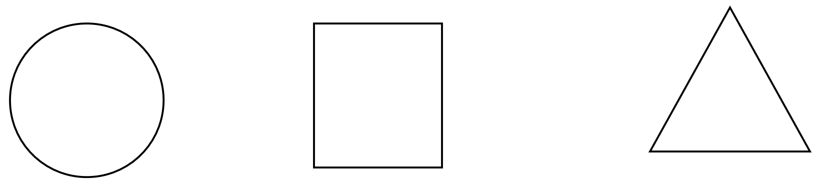
THE SUN IN YOUR HANDS

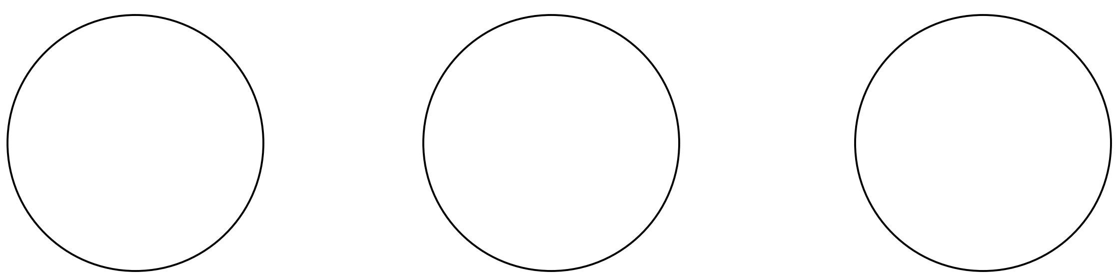
- When you perform the magic mirrors experiment you observe the following puzzling facts ?

1. When the reflected image is taken up on a nearby screen, it is the same shape as the mirror.

   Like this_:



2. When you take the image on a wall far away, all the three images are round in shape , like this



- To understand this transformation, you must have slowly increased the distance between the screen and the mirrors and observed how the triangle and square gradually becomes a circular disc.
- What is this circular disc ?
- What happens if we use a smaller mirror , i.e. if we reduce the size of the hole in the mask covering the mirror ?
- Why does a smaller mirror not give us a smaller image at a long distance ?
- Without telling the viewers the answer, by discussion, bring them to realise that the image is circular because it is the image of the sun. The mirror is acting as a pinhole camera.

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Experiment: the sun image

By increasing the distance between the screen and the mirror you can get a bigger and bigger image of the sun. In fact, you will discover that the diameter of the image is always roughly one hundred and ten times smaller than the distance between mirror and screen. At 100 metres, we will get a sun image which is almost one meter across. So we can use this idea to construct a powerful solar telescope and see what is happening on the surface of the sun. We can use it to see sunspots and show them to our friends.

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Experiment : Seeing sunspots , if they are there.

The photograph of sunspots has been obtained by using just one such solar telescope which I made in 2004 to observe the transit of Venus. It was taken during a lecture at Ferguson college Pune. You too can get a wonderful and exciting image of the sun, as big as you wish.

Equipment :
A PORTABLE DARKROOM

To see the image properly you will have to create a room which is as dark as possible in which to take the image or a portable darkroom.

Equipment : A Stable Mount

The second thing you need is a very stable mount for your small mirror, which you can adjust carefully. Any telescope is pretty useless unless you have a good and steady mount. Otherwise, the smallest motion of the mirror will make you lose the image.

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Mirror Projector with Ball Mount

You can make a beautiful mount by buying a large plastic ball and filling it with sand. A large spherical plastic *lota* will also do.

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Experiment : The Rotation of the Earth
How big is the sun ?

- Now we will discuss what we can discover about sunspots, the sun and our earth with our powerful solar telescope.
- Experiment : The rotation of the earth, once in 24 hours.
- Experiment : The Sun is 110 times as far as it is big.

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Experiment : The earth rotation and star movement

- Mount a straight sighting tube on your ball mount.
- Using it like a telescope , or like a rifle barrel, look through the tube and take aim on any star. After a few minutes, without moving the ball again look through the tube. Now you cannot see the star. Why ?

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Experiment : DhruvTara

- Look towards the north and identify the pole star (Dhruva tara) in the sky. Point your instrument so you can see dhruva tara when you look through the tube. After 15 minutes again look through the tube without moving the ball on its mount. You can still see dhruva tara.
- Look through the tube after one hour, after two hours, after 25 hours, after 49 hours, after three days or three weeks or three months …without moving your ball on its mount – you will always see Dhruva tara.
- This is because Dhruva tara does not move in the sky at all. (In fact it moves just a little bit, which you can hardly see, but you might be able to observe this movement with a very thin tube).
- All the stars and planets move in the sky except Dhruva tara. Why ?

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EXPERIMENT : MEASURING YOUR LATITUDE

The next thing you need to do is to measure the angle made by Dhruva tara above the horizon. Since Dhruva tara does not move, that angle is fixed. It does not change. This angle is just the latitude of the place where you are. But you will need to make equipment to measure the angle.

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Equipment : The Angle Meter

Make an ‘Angle-Dangle meter’ and also learn how to use it to measure distances. It is really quite easy to make an angle dangle meter using a matka with a round bottom as a ball mount, and a big protractor.

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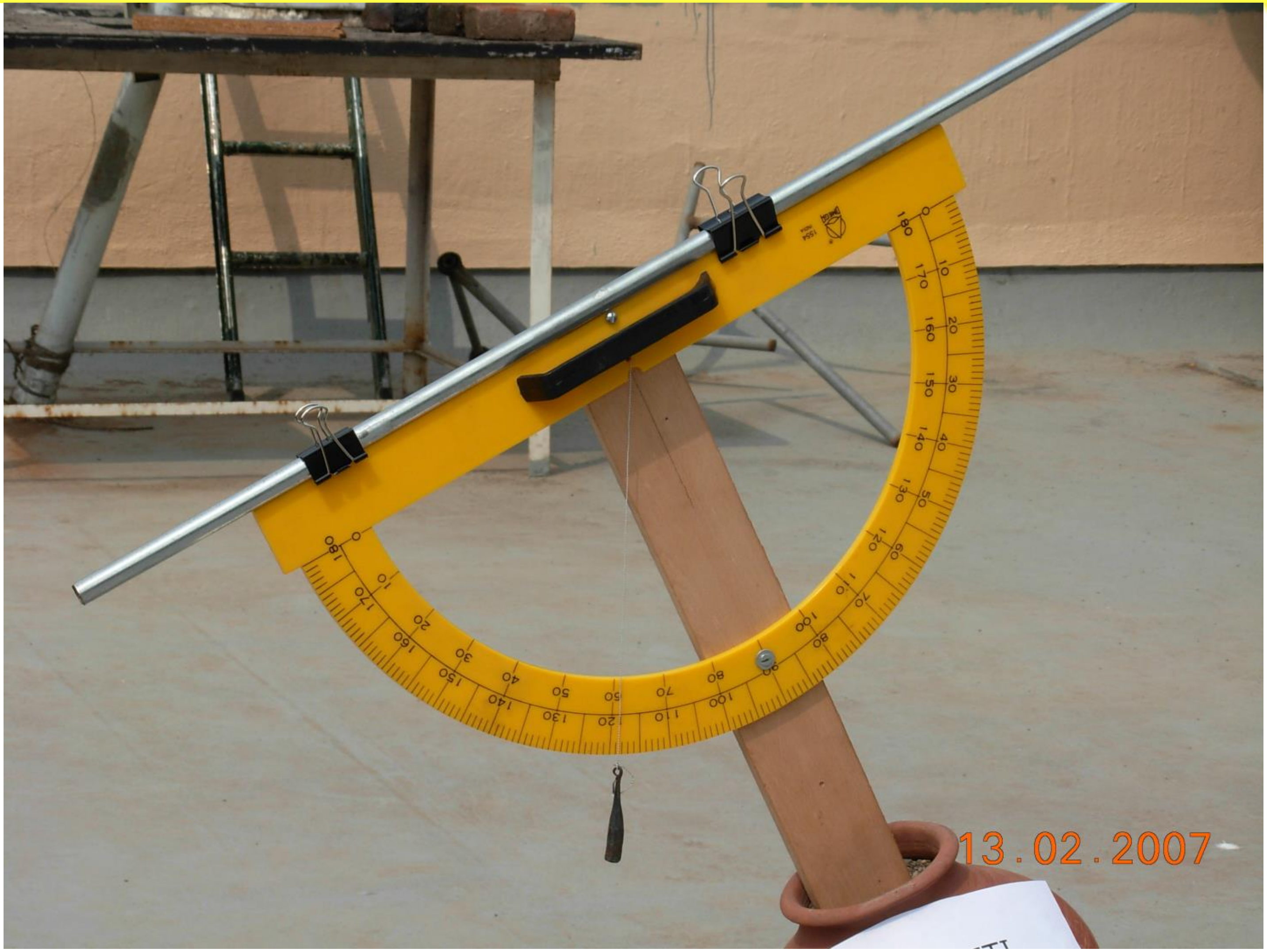
The Angle Dangle Meter
Measure Latitude with Dhruvatara



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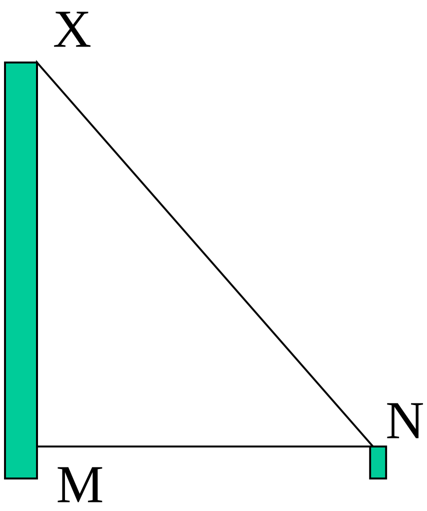
Measuring distances by measuring angles

Of course, when you have made your angle dangle meter and fixed it on a ball mount, you have made a fine scientific instrument, with which you can measure the height of a building, the radius of the earth, and the distance of the earth from the sun. How ?

EXPERIMENT : MEASURE THE HEIGHT OF A BUILDING USING THE ANGLE METER



Let us begin by measuring the height of a tall building, without walking up to its terrace. Keep your angle dangle meter with its ball mount on a stool , and move the stool to such a distance away from the building such that the angle XNM, (when you take aim at the top of the building), is 45 degrees. At this point, the distance of the stool from the building is just equal to the height of the building minus the height of the stool.

SIMILAR TRIANGLES

- You could also keep the stool anywhere, and measure angle XNM from that position, which may be different from 45 degrees. Then use similar triangles and graph paper.
- Using similar triangles, we can measure the height of the building without climbing it. Can we can use similar triangles to measure the distances of the sun and the stars without having to travel there ?

Equipment : The Geosynchron.

- We learn in school that the earth rotates around its axis once in a day , and that it also revolves around the sun once in a year. A geosynchron model helps us to understand this
- Take a large spherical globe and mount it like a ball mount so that you can see Dhruva tara while looking through holes at the north and south poles. You can use the plastic globe models of the earth which are available in most schools , (or else, even a round matka.) Rotate so that India is on top. The Geosynchron is ready for use.

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04 . 03 . 2008

- PARALLEL EARTH, SAMANTAR PRITHVI

- What is a geosynchron (GS) ? It is a model of the earth which is exactly parallel to our real earth. India on our GS is parallel to real India. Australia on our GS will also be parallel to Australia in its real position in the southern hemisphere.

- When it is noon in India, the sun will be right above our GS and it will be noon on our GS. When the sun is setting in real India, you will see that it is also setting for the small India map which is on the GS. In fact whatever time the sun is showing in real India, the same solar time will be seen on the India which is on our GS. Geosynchron means 'same earth time'. It could also be called a Samantar Prithvi. See the shadow cast by a human figure standing on India on the GS and compare with your shadow.
- By the simple act of fixing the line of sight of the tube onto Dhruva tara, we have created a parallel earth which remains parallel to the real earth not only as the earth rotates around its own axis, but also as the earth goes around the sun in one year.

Geosynchron :
Samantar Prithvi

- Why does Dhruva tara always remain fixed ? This is because the earth's axis, like the axis of a spinning top, always points in a fixed direction, and Dhruva tara happens to be in that direction. Secondly, because Dhruva tara is very very far away, so that even if the earth moves round the sun, that movement is very small compared to the distance of the sun and earth from Dhruva tara.
- Dhruva tara is not the only celestial object which appears to remain fixed in the sky. There are some man made satellites which also appear to be fixed in the sky. These are the geosynchronous satellites on which are fixed the antennas, receivers and transmitters which are used for mobile phone and internet telecommunications. These satellites are all at a height which is tens of thousands of kilometres above the earth's surface. At this height, the period of rotation of the satellite around the earth is equal to the period of rotation of the earth and therefore the satellite appears to be fixed above the earth.

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- For two completely different reasons two kinds of celestial objects appear to be fixed in the sky, while everything else moves. Dhruva tara, because it is extremely far away and because our earth's axis points at it . Geosynchronous satellites, because they are just so far away that they revolve around the earth at the correct speed.
- Supposing you were sitting on a geosynchronous satellite which is just above India and looking down on real India from outer space. You would see the sun rising and setting on India. You would see the line of light and shadow which separates day from night slowly rotating around the globe once in 24 hours. You can have the same experience by standing next to your geosynchron on an open ground and looking at it at different times of the day

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Equipment :Very Long Focal Length Lens (VLFL)

- It is commonly believed that a convex lens concentrates the light from the Sun. This however is true only if the focal length is small. As the focal length of the lens increases the size of the Sun's image increases. The relation is the same as for a pinhole projector.

  Image diameter = focal length of lens / 110.

- For a very long focal length (VLFL), the diameter of the Sun's image can be quite large, larger than the lens itself. Navnirmiti has developed VLFL lenses with focal lengths of 4 metres and 10 metres. The second lens gives a large image of the sun more than 9 cm in diameter.

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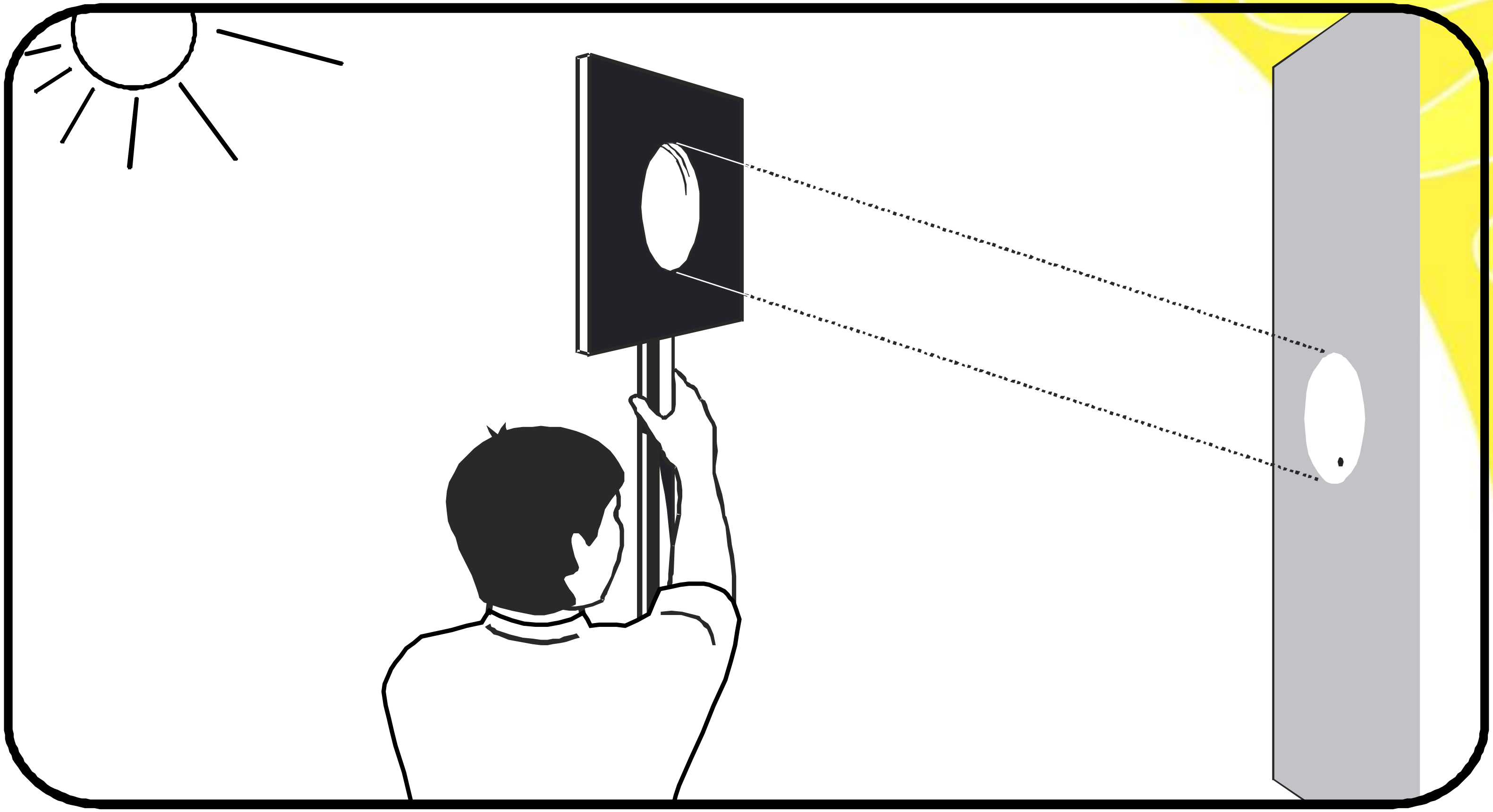

Very Long Focal Length Lens

Image diameter =

focal length / 110

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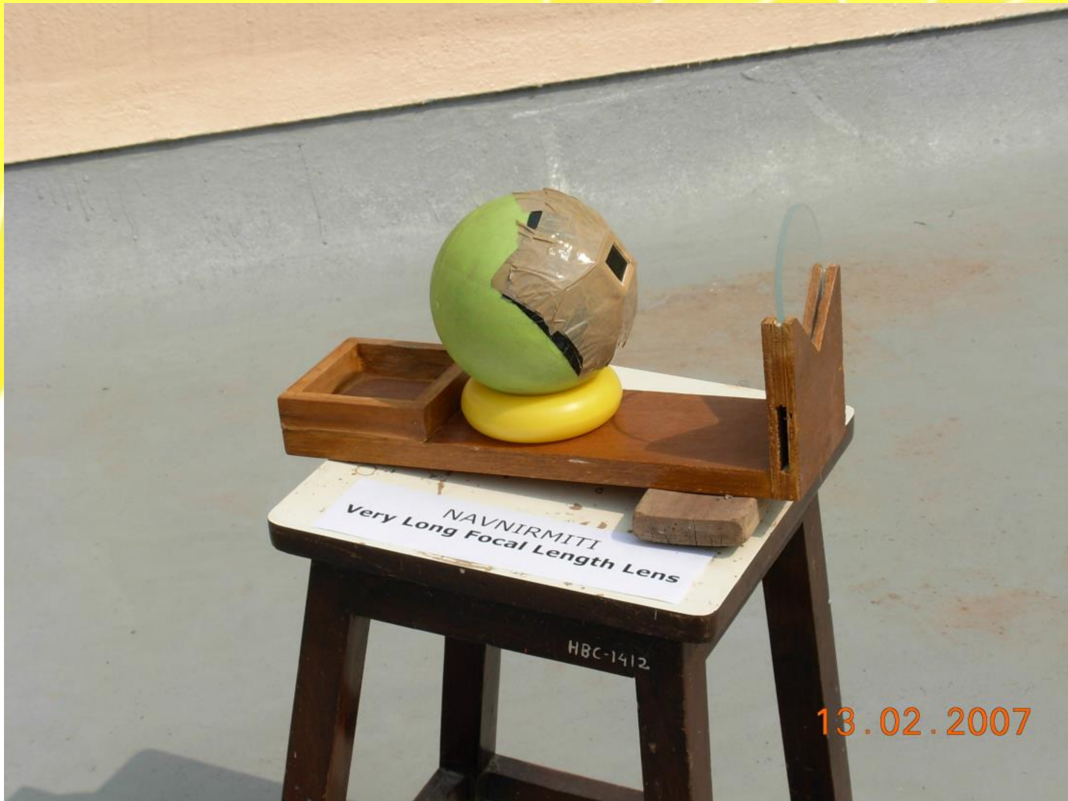
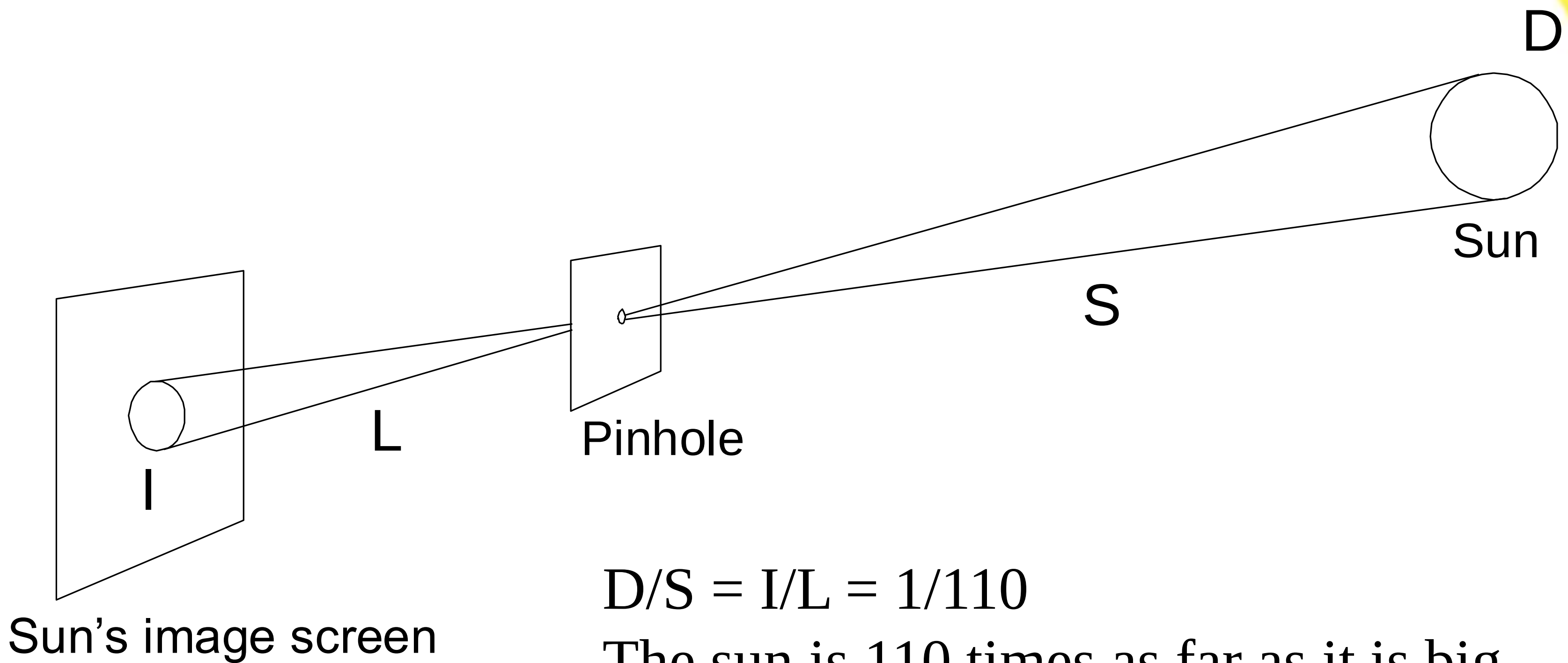


Ball Mirror and VLFL Lens

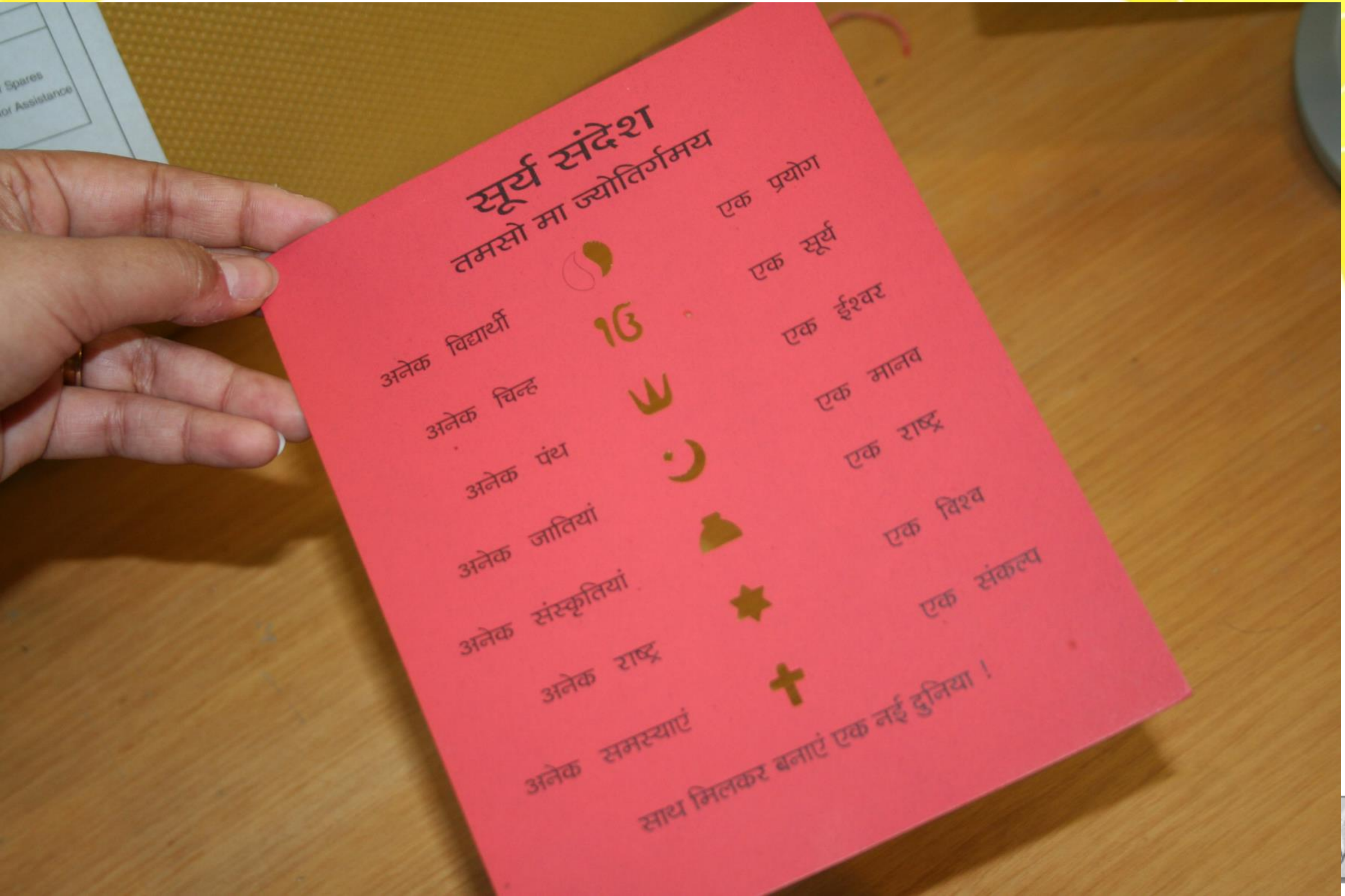
Why 110 ?



$D/S = I/L = 1/110$

The sun is 110 times as far as it is big.

Equipment : The SURYA SANDESH SUN CARD



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Experiment : PHASES OF THE MOON

- Place a white ball so that it appears the same size as the moon. It is a coincidence that the moon also is 110 times as far as it big. When the ball is kept at a distance of 110 times its diameter from the observer it too will appear the same size as the moon.

- At a time when you can see both the sun and the moon in the daytime, hold the ball so that it is in the same line of sight as the moon, so that it appears the same size as the moon. Can you now see the phase of the moon on your white ball ?

Equipment :Universal Time Reckoner

Universal Time Reckoner

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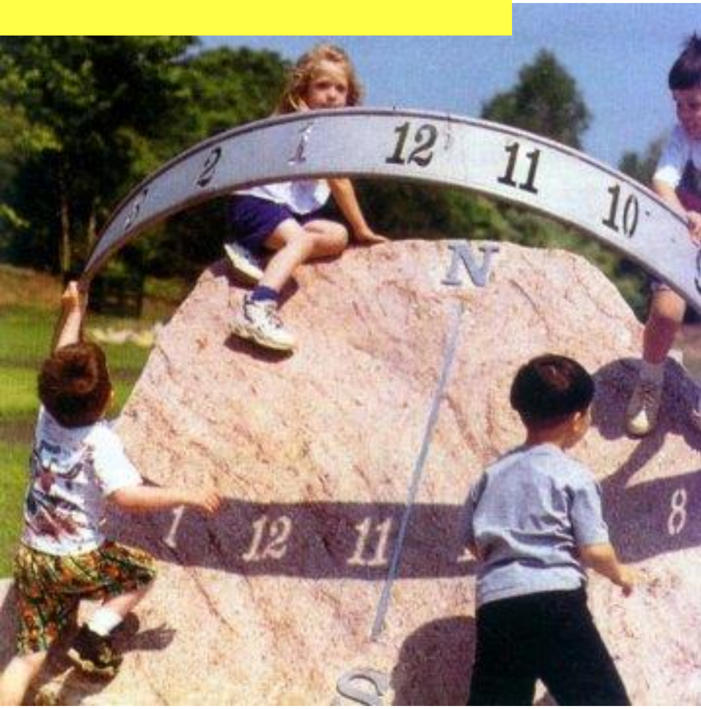
Sun Dial



Equipment: Sun Dual

Measuring the month and date

The dial as gnomon
The gnomon as dial

Sun Duality

Longitude = Time of Day
Latitude = Day of Year

The Sun Dual :
Both a clock and a calendar

Like electric current and magnetic field lines

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Homemade Telescope

Ball & Mirror with VLFL Lens

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Set up a terrasun lab on every school terrace

More Experiments

Experiments that you can do with your terrasun lab

- Measuring the radius of the earth
- Measuring the relative distance of Venus and Earth from the sun (This can be done on January 14th/15th 2009)
- Measuring the distance of the sun
- Measuring the diameter of the sun

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More Experiments

- Discovering the rotation of the sun around its axis

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More experiments

• Predicting where the sun is in the sky mathematically and verifying this with a sun dual
• Predicting the length of the shadow of an upright pole and verifying this by measurement
• Finding out the relation between the phases of the moon and the moon- earth- sun angle.

This will give students practice in high school geometry and an introduction to the concept of mathematical science.

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Prepare for

- Total Solar Eclipse July 22nd 2009
- Transit of Venus 2012.

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