

PARTHA GHOSE



DIPANKAR HOME



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Dr. Partha Ghose, of the S.N. Bose National Centre for Basic Sciences and Dr. Dipankar Home, of the Physics Department of Bose Institute, Calcutta, with their major research interests and activities in quantum mechanics and fundamental particles, have collaborated with each other and with others in the communication/dissemination of scientific information and concepts through both the print and video media, such as over the Doordarshan on which Dr. Ghose was one of the anchormen of the popular *Quest* series, and periodicals like *2001*, to which they have contributed the popular 'Inquiry' columns. To the making of their latest collaborative endeavour, *Riddles in Your Teacup*, they bring a rich expertise gathered from their sustained experimentation in science communication.

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## Preface

**“The most beautiful experience we can have is the mysterious. It is the fundamental emotion which stands at the cradle of true art and true science. Whoever does not know it and can no longer wonder, no longer marvel, is as good as dead, and his eyes are dimmed”.** -Albert Einstein.

One of our greatest pleasures over the last few years has been interacting with young people and “playing” with physics: trying to understand commonplace phenomena in terms of basic physical principles and delighting in their beauty, profundity, generality and their subtle interplay with reality.

Our familiarity with natural phenomena and the ordinary things that happen everyday around us rob them of their mystery and makes them seem obvious to us; we stop wondering at them. Yet more often than not they conceal delectable surprises and puzzles. Identifying and cracking them has been a fascinating quest that has given us countless hours of pleasure.

In his famous autobiography, Richard Feynman recalls how one day he saw a person in the Cornell University cafeteria fool around and throw a plate in the air. Feynman saw the red medallion of Cornell on the plate go around faster than the wobble. He started to think about it and “play” with its physics. He says, “the diagrams and the whole business that I got the Nobel Prize for came from that piddling around with the wobbling plate”. So, to our young readers in particular, our plea is: look out for the subtle and the profound in the familiar and the seemingly trivial; don’t brush it aside. Who knows, you might be throwing away the Nobel Prize.

This book has grown out of our regular columns in *Science Today* (now called *2001*) and *Amrita Bazar Patrika*. We owe a lot to our enthusiastic readers who have helped not only with answers but also with problems. Some of these problems appear in this book. Unfortunately, our benefactors are far too many to be acknowledged individually. They have already been acknowledged in our columns. The initial impetus, of course, came from the Television programme “Quest” in which one of us had the privilege to participate for a while. Two books have also been sources of inspiration for us. They are *The Flying Circus of Physics* (Walker, Wiley, 1975) and *Clouds in a Glass of Beer* (C.F. Bohren, Wiley, 1987).

We have arranged the book into several sections, not according to the conventional partition of physics into heat, light, sound and so on, but according to whether we face the puzzles in and around our kitchen, out there in nature, on the play ground, watching a movie, or reading a novel. We find this way of classifying more interesting and natural. The last section contains a few riddles that, to the best of our knowledge, still remain unsolved or whose solutions are not that straightforward. We urge you to have a go at them in the spirit of Richard Feynman.

We hope you enjoy reading this book. Please do so critically. And if, as a result, you are able to solve one or two of the open problems or notice new ones or have anything to say about the answers we have given, do write to us, care of the Publishers, about them. We would love to hear from you.

We have enjoyed collaborating with **Suparno Chaudhuri** who has done the illustrations and cartoons.

Calcutta

November 1989

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## Kettle Croon

### Physics around the Kitchen

“All our knowledge brings us nearer to our ignorance.”

- T S Eliot

## Kettle Croon

### Physics Around The Kitchen



## Kettle Croon



Boiling water in a kettle is a daily chore for most of us. We are all familiar with the hissing sound {called the “singing” of the kettle) that starts a few moments after the kettle is put on the fire. This sound gradually increases and then suddenly drops when the water starts to boil. In fact, we know from the sudden drop of the sound that the water is ready, boiling. Have you ever wondered what causes the kettle to “sing”?

## Spoon in a Teacup



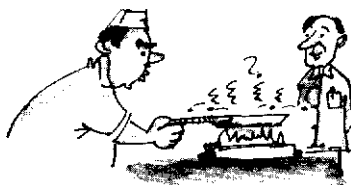
The experienced housewife often puts a metal spoon into the china cup before pouring hot tea into it. Why? Which is safer to use, a thin-walled cup or a thick-walled one?

## Don't Lick an Ice Tray



Have you ever tried to hold a really cold frosted ice tray? If you have, you must have noticed that your fingers tend to stick to the tray. Why? Don't ever try to lick the tray - it will be a very painful experience!

## From Fermi to the Frying Pan



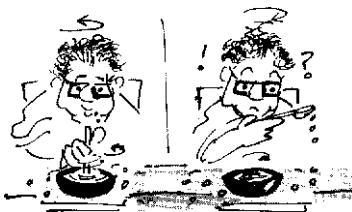
The celebrated Italian physicist Enrico Fermi once asked a student during an examination : “The boiling point of olive oil is higher than the melting point of tin. Explain how it is then possible to fry food in olive oil in a pan”. (Italian saucepans are wholly made of tinned copper). What is the answer?

## Leaping Liquid



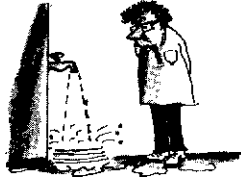
One of the regular headaches for a housewife is the nuisance caused by milk spilling over when boiled. She has to keep a constant watch and stir the milk to prevent it spilling. Some say an easy way out is to keep a spoon immersed in the milk from the beginning. Why does milk {and also ‘dal’) have this peculiar property?

## Soup Swirl



Next time you have a thick soup at lunch, or prepare a paste of starch, give it a good swirl, lift your spoon and watch for a few seconds. You will notice that just before the turning stops, its direction reverses momentarily. This phenomenon illustrates an important characteristic of real fluids, namely, ... what?

## The Kitchen Sink



Next time you are in your kitchen, turn on the sink tap. Notice that on striking the sink, the water spreads out in a thin layer up to a certain radius, after which the thickness increases abruptly, creating a circular wall of water around the falling stream. A similar wall is also produced when a stream falls on a flat floor. You must have seen this phenomenon innumerable times. Have you ever stopped to wonder 'why'?

## Honey of a Problem



Pour out honey gently from a jar. If you intercept the thin stream of falling honey with a knife, you will see that the honey above the knife shrinks back and disappears into the jar. Don't pour out the honey too quickly; let it just trickle down. What do you think causes this antigravity effect?

## Einstein in Your Teacup



Erwin Schrodinger was a famous physicist who wrote down an equation for atomic particles that has replaced Newton's second law, which is now known to be valid only for ordinary-sized objects. Schrodinger's wife remembered Einstein every time she poured her tea. This is because it was Einstein who first explained to her and her husband why the tea leaves, which are heavier than the liquid, collect at the centre of the bottom of the cup when the tea is made to rotate by a spoon. Next time you have tea, turn it with your spoon before pouring in the milk and notice where the leaves settle. Why do you think the leaves settle at the centre and not get pushed to the walls by the centrifugal effect?



## Our Daily Bread

“The essential point in science is not a complicated mathematical formalism or ritualised experimentation. Rather the heart of science is a kind of shrewd honesty that springs from really wanting to know what the hell is going on.”

- Saul Paul Sirag

## Our Daily Bread



## Have a Drink



When we drink, we bring the glass or cup containing the liquid near our lips and suck in the liquid. What makes the liquid rush up into our mouth? Take a bottle of some drink, cover its mouth with your lips and try to suck in the drink without inverting the bottle above your mouth. What happens?

## Soap and Dirt



How does soap help remove dirt from our bodies and clothes? Any idea?

## A Burning Flame



Next time you carry a candle or a burning matchstick, notice that the flame is initially deflected backwards. Which way will it deflect if you carry it in a case or protect it with your hand?

## Funny Funnel



You must have noticed while pouring a liquid into a bottle through a funnel that you have to lift the funnel from time to time when the liquid collects in the funnel and does not flow down. Do you know why?

## Blow Out!



Who hasn't blown out a candle or watched one being blown out by a gust of wind? Even such commonplace a phenomenon is however quite baffling. Why should a candle be blown out in spite of a supply of more air (containing oxygen which helps burning)?

## Iron It Softly



It is common practice to sprinkle some water on a starched cloth before pressing it with a hot iron. Why does it help to sprinkle water and use a hot iron?

## Fire! Fire!



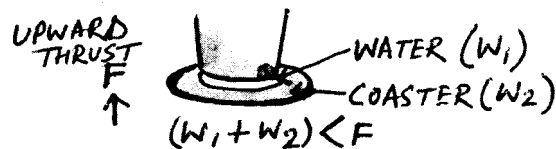
Whenever there is a fire we wish to extinguish, we think of water. The fire brigade uses water to put out big fires; a housewife sprinkles water on the kerosene stove after cooking is over. What makes water an effective fire extinguisher?

## Ice Fumes



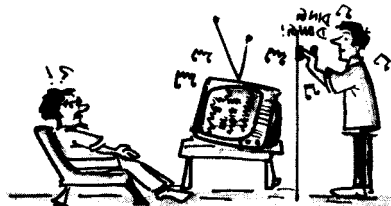
Have you noticed that when exposed to air, a large slab of ice appears to give out fumes? What are these fumes and why do they form?

## Coasting Along



Why does a coaster tend to stick to a wet-bottomed glass when the glass is lifted?

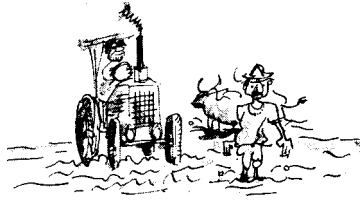
## Of Doorbells and TV Screens



Have you noticed that whenever somebody rings your doorbell, there is a disturbance on your TV screen? What has the doorbell got to do with the TV screen?



## Tractors and Buffaloes



A heavy crawler tractor is able to operate on soft, muddy ground but the farmer's as well as his buffaloes' feet sink. Why?

## Dropping a Bottle



Imagine you are travelling in a car. You have a glass bottle in your hand. In which direction relative to the moving car should you throw it to minimise the danger of its breaking on hitting the ground?

## Swimming Underwater



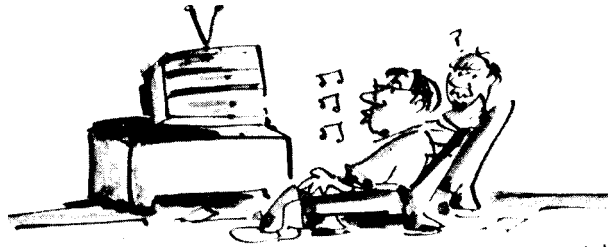
Have you noticed that when swimming underwater, you can see much better if you wear goggles. Why?

## Blinding Light



We are annoyed when cars coming from the opposite direction have their headlights on, because the bright light dazzles our eyes. Also, when there is a power cut, for a while we are unable to see anything. Then gradually our eyes get adjusted and we are able to discern faintly the objects around us. Why do our eyes react to light the way they do?

## Hum with Your TV



Philip C, Williams, Florida, U.S.A, observed (Nature, Volume 239, p.407, 1972) that humming at a certain pitch while watching television from a distance caused horizontal lines to appear on the television screen, which were visible only to the person who was humming. These lines could be made to remain stationary or move up or down by altering the humming pitch. Isn't that queer?

## Coiling Chocolate



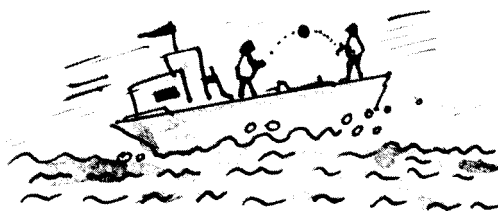
The coiling of thick molten chocolate as it is poured onto a plate or a slab of ice-cream must have struck you as odd. What on earth makes it coil?

## Rest in a Hammock



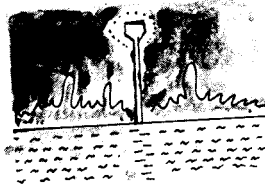
Why is it pleasant to lie in a hammock though the pieces of rope that go to make it are by no means soft? Why is it pleasanter to sit on a wooden chair rather than on a flat-topped stool?

## Play on a Ship



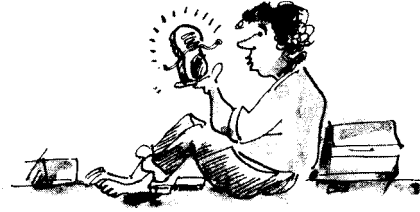
Two friends are playing with a ball on board a ship moving at a steady speed. One is standing nearer the aft and the other nearer the bows. Does one of them find it easier to throw the ball to his partner? (Ignore wind effects)

## Long and Broken



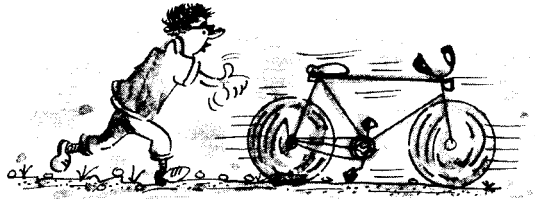
The image of a street lamp on a lake or pond often appears elongated and broken; a very common sight. Do you know why?

## Boot Polish



A friend's son was polishing his shoes the other day. Neither the sticky polish nor the brush had anything that he could connect with the shine of the shoes. He was puzzled. Can you help?

## Ride Along



A cycle (or a thin rimmed wheel) at rest cannot be made to stand on the ground, but given a rolling motion, it does not fall. What do you think is the reason?

## Whistle Melodies



People often whistle melodies through their lips when in a merry mood. What exactly happens to produce this sound?

## Tear a Paper



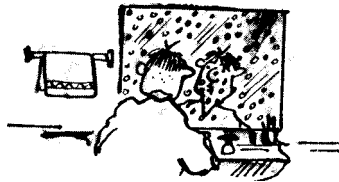
When you tear up a piece of paper, you can hear a characteristic sound. Notice that the quicker you tear it, the higher is the pitch of the sound. Any idea why?

## Woof, It's Cold !



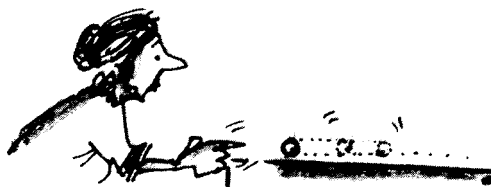
Have you been to a hill station? It's usually cooler up there, isn't it? Why is it cooler at higher altitudes than at the sea level, even though you may be several thousand feet nearer the sun?

## Foggy Mirror



Many of you must be familiar with the fogging of the mirror in the bathroom after a hot shower. The fogging of car windscreens during heavy showers is also a familiar sight. There is a simple way of avoiding this kind of fogging. Do you know what it is and how it works?

## Roll a Coin



Place a rupee coin vertically on its edge on a table. It tends to fall on its side, Now give it a push - it rolls forward steadily for a while without toppling. Why?

## Play Time

“We dance around a ring and suppose, But the secret sits in the middle and knows.” - Robert Frost

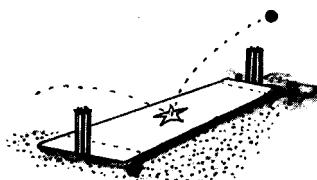


## Raman's Billiard Ball Problem



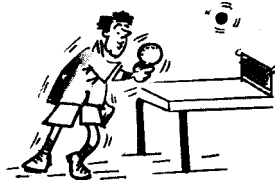
Raman was passionately curious about everything that happened around him, including the sharp click that is heard when two billiard balls collide. Did you ever suspect that even such a simple and common phenomenon might involve unexpected subtleties of physics? Raman made a careful study of these clicks and arrived at some unsuspected conclusions. For example, he found that the intensity of the click varied with the direction around the billiard table. Can you guess in which direction it is a maximum and why? It might be well worth your while to do the experiment yourself and find out. If you cannot find billiard balls, try with marbles. We are grateful to Professor S. Ramaseshan (Raman Research Institute, Bangalore) for drawing our attention to this beautiful problem.

## Play Cricket



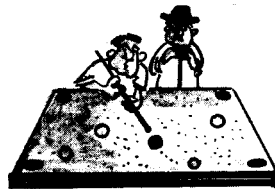
A cricket ball often moves faster after pitching on a smooth wicket. Have you noticed that? What do you think is the reason?

## Top Spin



Tennis and table-tennis players often use ‘top spin’, which makes the ball dip and land earlier than expected. Why does the ball’s spin (about the diameter perpendicular to its direction of motion) make it dip?

## Follow Shots



In a game of snooker or billiards, one often sees “follow shots” in which the cue ball follows the ball (of exactly the same mass) it hits for a time, even when the ball which it hits picks up its full speed. This seems to violate the principle of conservation of energy. How would you explain such follow shots?

## 4

## Flow, Fluid Flow!

“So long I have seen only with my eyes; now I want to perceive through my intellect.” - Rabindranath Tagore

*Flow,  
Fluid Flow!*

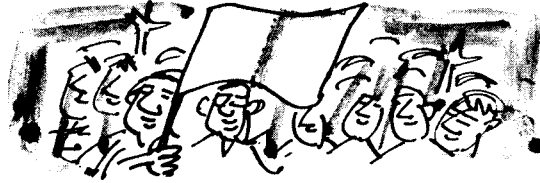


## Smoky Swirls



You must have noticed that when there is no breeze or draft, smoke from a cigarette resting on an ashtray rises steadily and smoothly up to a point and then suddenly breaks into swirls. Why?

## The Fluttering Flag



The fluttering of a flag in the wind is one of the most common sights. Yet, how many of us have ever bothered to ask, why? Do you know what causes a flag to flutter in the wind?

## The Puzzling Balloons



A friend, Professor Arthur D. Yaghjian {Concord, Massachusetts, USA) was once travelling in a car with his family, carrying helium-filled balloons. He noticed that whenever he accelerated the car, the balloons surged forward and crowded around his shoulders! Every time he put on the brakes, the balloons moved backwards and pressed against the rear window! Why did the balloons behave in such a crazy way?

## An Anti-gravity Effect



If you dip a capillary tube (a tube with a very fine bore) into a liquid, the liquid rises inside the tube. This is the mechanism that works in blotting papers which consist of fine capillary tubes. If you keep one corner of a towel dipped in water, gradually a large portion of the towel gets wet. Again it is capillarity in action; a towel has thousands of fine capillary cotton tubes through which water can rise. The question is : what is the source of energy that makes the water rise?

## Pour a Liquid



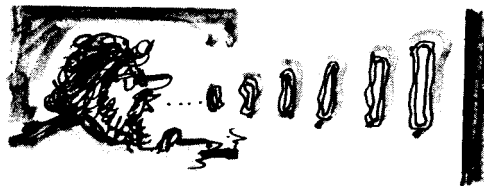
When you pour fruit juice or milk or any such liquid gently from a container, why does it tend to run down the side and not drop straight off from the lip? What factors determine how far down it adheres to the side of the container?

## The Tapering Stream



Turn on the tap in your bathroom and watch the steady and smooth stream of water fall to the ground or into a bucket. You will notice that the stream narrows as it falls. Is there a force squeezing it together?

## Expanding Smoke Rings



Have you seen veteran smokers puff out smoke rings? These rings are technically called vortex rings. They are remarkably stable in still air and can travel considerable distances without distortion. If such rings are directed towards a wall, it is found that they expand as they approach the wall. Why does the proximity of a wall make them expand?



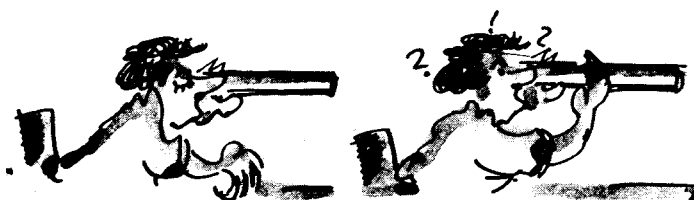


## Through the Palm Strangely

“It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts.... The difficulty is to detach the framework of fact - of absolute undeniable fact - from the embellishments of theorists.” - Sherlock Holmes



## Through the Palm Strangely



Roll a piece of paper into a tube. Hold it with one hand, say, the left hand, and look at a distant object through it with your left eye, keeping your right eye closed. Now, bring your right palm in front of your right eye so as to touch the tube, and then, open your right eye as well. You will see the distant object clearly through a hole in your right palm! (Both hands should be about 15-20 centimetres from your eyes). It's fantastic, isn't it? How do you explain it?

## It Does Not Pour Out



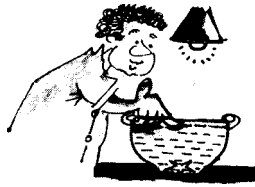
It is usually stated in text books that if you fill a glass completely with water, cover its mouth with a stiff card and invert it, the card sticks to the mouth of the glass and does not drop. Actually you will find that you do not need to fill the glass completely, just pour some water into it, cover its mouth with a stiff card and invert it, and the card will stay in its place. What keeps it stuck to the glass?

## Darting Pepper



Take some water in a glass and sprinkle some pepper on it. Now rub a fingertip on a detergent soap and touch the water surface. You will be amazed to see how instantly the pepper particles will fly away from the spot in all directions. What makes them do that?

## The Silvery Shadow



Take a bowl of water, hold it under a bright light, lower your index finger so as to dip into the water and watch the shadow on the bottom of the bowl. You will be surprised to see that as soon as your finger touches the water, the shadow of the tip of the finger splits into two and there is a silvery lining along its edge. A similar effect can be seen beautifully when an insect skates along the surface of water and bright light falls on it from above. What causes these splittings and silvery linings to appear?

## Weigh Yourself



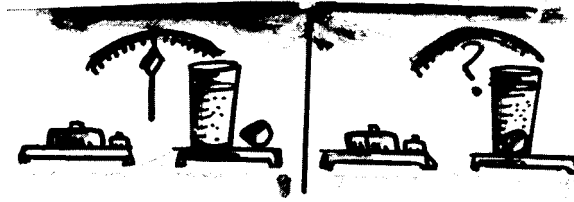
Next time you weigh yourself, notice what happens when you bend forward. You will find that while bending forward, you seem to lose weight! Try another thing. Lift one of your arms quickly. This time you will find that while lifting your arm, you seem to gain weight! Why?

## Defying Gravity



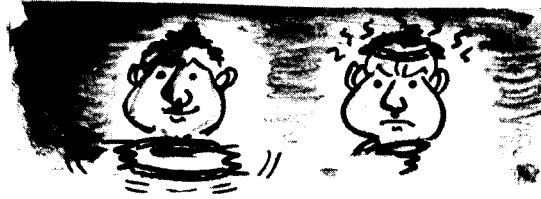
“Water will not pour out of a rotating vessel - even when the vessel is bottoms up. Rotation prevents it”, wrote Aristotle some two thousand years ago. If you swing a bucket of water fast enough as shown in the figure, the water will not spill. Why won't it spill?

## Weigh a Stone in Water



Place a glass of water and a stone on one pan of a balance and balance them with weights. Then drop the stone into the water in the glass. What happens to the balance? And why?

## The Puzzling Rubber Band



Take a thick rubber band, stretch it quickly and hold it against your forehead - you will feel it distinctly warm! This is contrary to what one would normally expect. Remember that quick expansion of a gas usually cools it. Why does the rubber band behave in a contrary way?

## Comb Your Hair



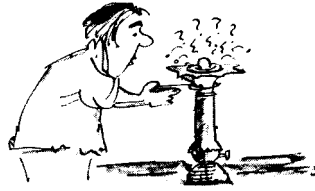
When your hair is completely dry, you can try the following experiment. Take a small plastic comb and comb your hair or rub the comb with a piece of flannel. Then go near a tap and turn it on gently so that water just trickles out. Hold the comb near the water. You will find that the trickle becomes a steady stream and is deflected by the comb! Why? (The experiment works best in dry weather conditions).

## The Woolly Winter Coat



Keep a thermometer wrapped up in your winter coat. Do you expect to find a difference in its reading after a couple of hours? Now take two ice cubes. Keep one on a dish and wrap up the other one in your coat. When the ice on the dish melts, unwrap the coat. What do you expect to find?

## The Paper Kettle



The picture shows an egg boiling in water in a paper pot. Impossible, you might think. Won't the paper catch fire and the water spill over and put out the fire? Try the experiment yourself with a paper pot made of some stiff paper and attach a piece of wire to it to enable you to hold it over the fire. The fire will lick the pot but nothing will happen to it, and you can boil an egg in it. What do you think is the reason?

## The Jumping Draught



Arrange a few identical draughts or coins in a straight line so that the neighbouring draughts or coins touch. Hold the first draught lightly with your fingers and strike it sharply on its edge with a ruler. You will see that the last draught or coin will jump away, leaving the rest in their places. Why?

## Which Is Heavier?



Take two identical glasses filled to the brim with water, but one having a piece of wood floating on it. Which one is heavier?

## Tearing Wet Paper



It is common experience that it is much easier to tear wet paper than dry paper. Have you ever wondered why?

## The Invisible Pin



Stick a pin into the centre of a flat, round piece of cork so that it sticks out at right angles to its plane. Now float the cork in a bowl (with opaque sides) with the pin hanging downwards into the water. Provided the cork is neither too large nor too small, you would not be able to see the pin, however much you try, although the pin may be long enough for the cork not to hide it. Try this simple experiment yourself, and you will be convinced. Can you figure out why?



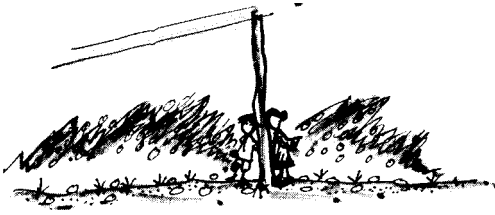
## 6

### Fact & Fiction In Movies & Novels

“Believe nothing, no matter where you read it, or who said it, no matter if I have said it, unless it agrees with your own reason and your own common sense.” - Gautama Buddha

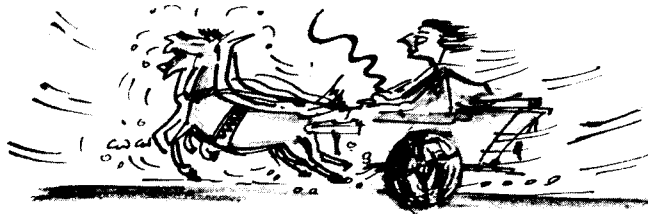


## The Humming Wires



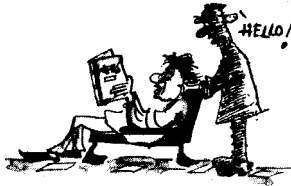
Many of you, we presume, have seen Satyajit Ray's widely acclaimed film *Pather Panchali* ('Song of the Road'). You would recall the enchanting sequence where Durga and Apu are running around in the field and listening with ecstatic wonder to the humming of the telegraph wires in the wind. Peter Sellers once wrote of this sequence, "It was so beautiful I could cry". Durga and Apu were perhaps wondering whether the sound was bringing any message from their father. What do you think? Why do telegraph wires hum in the wind?

## The Ben Hur Chariot Race



Have you seen the classic film *Ben Hur*? Do you remember the spectacular chariot race sequence? If you do, you would recall that after the chariots picked up a certain speed, the wheels appeared to turn slowly in the reverse direction. The same thing also happens with rapidly rotating fans. Do you know why?

## The Invisible Man



H.G. Wells created the invisible man in his celebrated story by the following trick: he made the refractive index of the invisible man exactly the same as that of air. So light rays simply passed through him without reflection or refraction. There is however a catch, a scientific fallacy involved in this conception. Can you figure out what it is?

## Can Lightning Magnetize a Sword?



There is a detective story (*The Royal Bengal Mystery*) by Satyajit Ray in which the detective Pheluda solves the mystery by arguing that the suspected victim was not murdered but was struck by lightning. He used the following clue: the iron sword held by the man had been magnetised. There was also circumstantial evidence that lightning had struck the neighbouring area. Do you think it is possible for lightning to magnetise an iron sword?

## An Oscar-winning Problem



Have you seen Richard Attenborough's Oscar-winning movie *Gandhi*? There is a scene in the film where Gandhi gives his cotton wrapper to a poor woman. Gandhi takes out his *chadar*, gathers it into a bundle and throws it into the river. The chadar gradually stretches out beautifully on the water as it floats towards the poor woman. Why does the crumpled chadar stretch itself out on the water? An Oscar-winning Problem.

## 36 - CHOWRINGHEE LANE

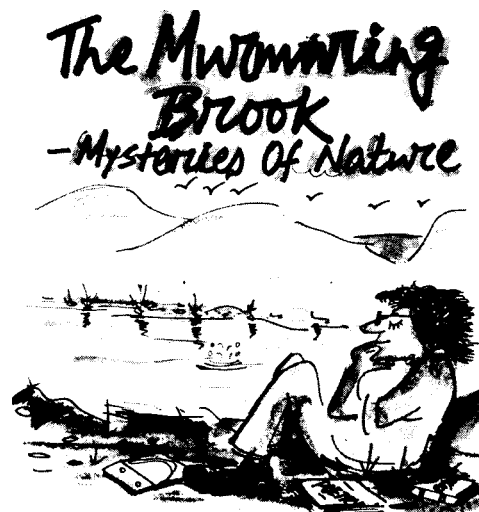


Recall the last sequence of the film *36 Chowringhee Lane*? Miss Stoneham turns up at her pupil's house on Christmas eve, wipes the frosty windowpane from outside and finds a boisterous party going on inside. Did anything in this scene strike you as scientifically fallacious?

7

## The Murmuring Brook Mysteries of Nature

“Nature! Out of the simplest matter it creates most diverse things, without the slightest effort, with the greatest perfection, and on everything it casts asort of fine veil. Each of its creations has its own essence, each phenomenon has a separate concept, but everything is a single whole.” - Goethe



## The Murmuring Brook



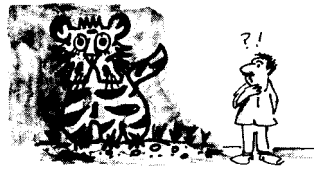
At some time or other in your life you must have spent a sunny afternoon lying on grass, listening to the murmur of a brook. It has a lyrical quality that has evoked creative responses in many a poet and musician. Do you know why the brook murmurs?

## VFly



One of the most beautiful sights is that of migrating birds flying across the evening sky in V formations. Why don't non-migratory birds fly in V formations?

## Tyger! Tyger! Burning Bright



You must have noticed that the eyes of a cat or tiger shine brightly at night even when very faint light falls on them. This does not happen, for example, with human eyes. What is the difference? And how does it help the cat or tiger?

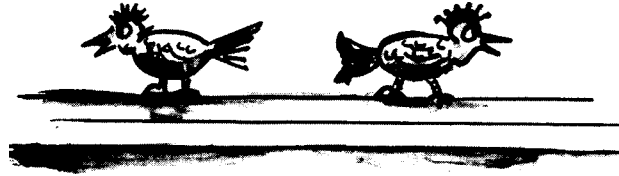
## The Elusive Cricket



Have you ever tried to listen to a cricket and locate it? The moment you think you hear the sound coming from a particular direction and turn your eyes towards it, it seems instantly to jump away to give you the slip. How do you account for this strange elusive character of a cricket?

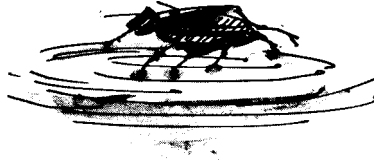


## Ignorance Is Bliss



You must have seen birds happily sitting on dangerous high tension electrical lines. Why don't they get electrocuted?

## Pond skater



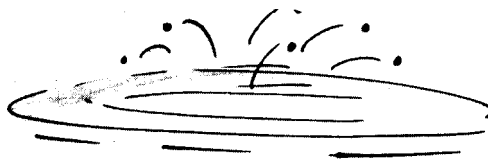
Insects darting and skating along the surface of ponds is a pretty sight. How do they manage to do that without sinking?

## Darkness at Noon



Breakers continually washing the shores are a beautiful sight. As the water rolls in and out, it leaves a mark on the beach. Wet sand looks distinctly darker than dry sand. Why?

## The Shape of Ripples



When a stone is dropped into still water, it produces circular waves that spread outwards. What shape, do you think, will the waves take in the flowing water of a stream?

## Sap in the Cap



How does sap move up tall trees?

As is well known, a vacuum pump cannot lift water columns beyond 33 feet because atmospheric pressure simply cannot support a taller column. Yet many trees are more than 33 feet tall. Some are two to three hundred feet tall. How are they able to pull water from the ground to their crowns?

## Blue, O Blue Sea



During his voyage to England in 1921 Sir C.V. Raman was fascinated by the deep blue of the Mediterranean. Raman did a simple experiment on board to test Lord Rayleigh's contention that this blue was due to reflection of the sky. What did he do and what conclusions did he draw?

## The Winter Veil



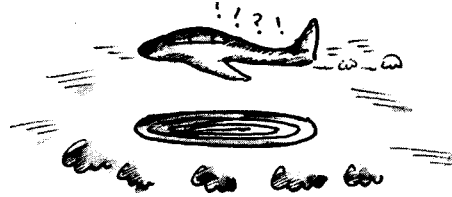
Winter is a season of smog in many places. Travelling past villages by dusk, you can see dense smoke hanging low over the thatched or tiled roofs. This is a familiar sight in the late autumn and winter but not in other seasons. Do you know why?

## The Ghostly Moon



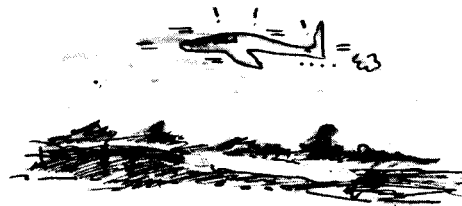
A few days ago we witnessed a total lunar eclipse. When the earth's shadow totally eclipsed the moon, it did not vanish out of sight altogether - it was still visible and looked faintly reddish. Why?

## Catch a Full Rainbow



On one occasion while travelling in a plane, Professor M.K. Dasgupta, the eminent radioastronomer, happened to look down and saw a beautiful sight - a complete and circular rainbow with the plane's shadow (on the clouds below) at the centre! Immediately on his return he related this to us. Why did he see a full circular rainbow?

## The Moon and the River



One of our colleagues was recently flying on a moonlit night high above a river. He looked out through the window and noticed to his utter surprise that the moon's reflection on the river was so large that it did not fit into the width of the river! What puzzled him was that the width of the river appeared to have decreased with altitude as expected, but not the moon's reflection. What could that be due to?

## Olber's Paradox



When we look up to the sky at night, we find it pitch dark excepting for the stars. Can you guess what the darkness of the night sky is really telling us about the universe we live in?

## Twinkle, Twinkle, Little Star



“Twinkle, twinkle little star,  
How I wonder what you are,  
Up above the world so high,  
Like a diamond in the sky.”

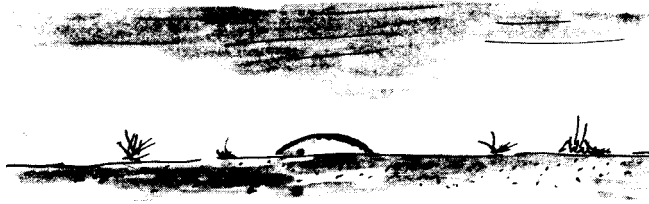
Why do only stars twinkle but not planets?

## The Blue Dome of Air



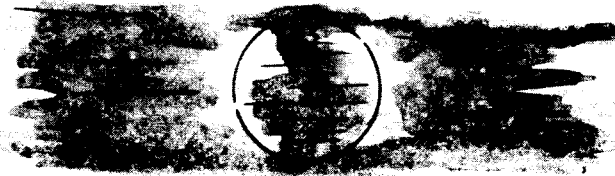
The usual argument explaining why the sky looks blue is based on the fact that the scattering of light by the particles in the atmosphere increases rapidly with its frequency (Rayleigh's Law of Scattering). Since blue light has a higher frequency than red, it is scattered more than red and hence the sky looks blue. But violet has an even higher frequency than blue. Then why doesn't the sky look violet?

## The Blue Zenith



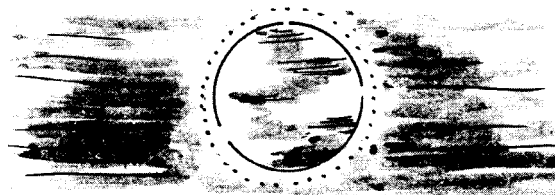
Have you ever noticed that the zenith (overhead sky) turns deep blue just after sunset? Any idea why?

## Once in a Blue Moon



You must surely be familiar with the phrase "once in a blue moon". Have you ever seen a moon or a sun which is deep blue like the sky? Well, it is indeed an extraordinarily rare sight. To the best of our knowledge, a blue moon and a blue sun were last authentically reported way back in September 1950. Robert Wilson, an astronomer attached to the Royal Observatory in Britain saw a blue moon and also a blue sun in Edinburgh. He even made observations with a telescope and drew the strange inference that the blue of the sun and moon was related to forest fires in Canada. What could forest fires possibly have to do with a blue moon?

## Halo Moon



Have you ever seen a halo around the moon? You must have. Do you know what causes the halo to appear?

## Give Your Brains a Racking

“In science we pay the highest respect to creativity, to originality ... we do not honour scientists for being right... it is never given to anybody to be always right. We honour scientists for being original, for being stimulating, for having started a whole line of work.” - Hermann Bondi

“Rouse up, Sirs ! Give your brains a racking To find the remedy we’re lacking.”  
-The Pied Piper of Hamelin



## The Intriguing Cork



Take a small piece of flat cork, wet it in water, and float it in a glass. You will find that it invariably drifts towards the walls. Keep pouring water gently. As soon as the glass is full to the brim, the cork automatically drifts back towards the centre of the glass and remains there. Obviously, this is connected with the reversal of the curvature of the water surface. Why does this reversal take place? And what precisely makes the cork drift towards the centre and stay there?



## Of Floating Blades and Wooden Sticks



Take two razor blades and two wooden sticks. First, put the blades gently in a tub or bucket filled with water so that they do not sink. Now slowly bring the blades towards each other by giving a slight push to one blade with your finger. You will find that when the blades are 3-4 mm apart they will automatically get attracted towards each other and will remain stuck till you part them. The same phenomenon is observed if instead of blades two wooden sticks are used. However, if you put one blade and a wooden stick in the tub, they repel each other if you try to bring them closer.

We urge you to repeat the experiment carefully with different materials and shapes and try to see if a general pattern can be established. Why do floating objects behave as they do?

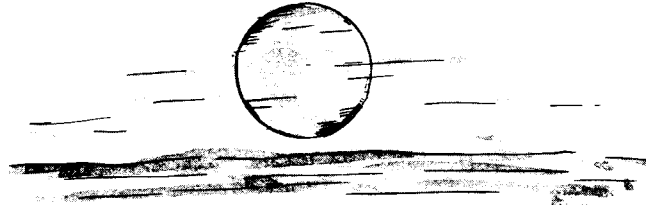
## Tippy Top



Look at the photograph reproduced here. Can you recognise the two bewildered men? Well, they are Niels Bohr and Wolfgang Pauli, two of the most celebrated physicists of this century. And the toy attracting their curious attention is the well-known 'tippy-top'. If you spin this top on its heavy spherical side, it quickly inverts itself and continues to spin steadily on its thin stem. But isn't that baffling?

Remark : The steady spinning of a top is essentially the result of its inertia of rotational motion, referred to as the conservation of angular momentum in technical jargon. The flipping of the 'tippy-top' implies flipping of its angular momentum direction, that is, a sudden change of its rotational inertia. It is friction which plays an important role here. Friction acts in a direction opposing the spin and gives rise to a torque tending to flip the top. But then, why doesn't it keep flipping again and again? Why is the position with the heavier side on the top more stable during spinning? Think about it.

## Larger Looms the Moon



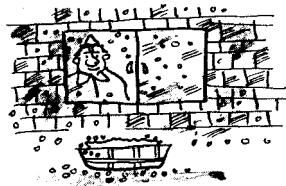
Have you ever noticed that the Moon looks larger near the horizon than when it is at the zenith? You must have, but perhaps most of you haven't thought about it much. L. Kaufman and I. Rock (*Science*, Volume 136, p.953, 1962) made a detailed study and established conclusively that the lunar size at the horizon is 1.2 to 1.5 times the size at the zenith: the moon gradually appears to shrink as it ascends. This effect persists in all atmospheric conditions. A protracted debate on this subject has been going on in learned journals. Some think it to be a naturally occurring example of the relativity of perceived size. But a really satisfactory explanation continues to be elusive. Perhaps you could now feel inspired to ponder over this?

## The Green Flash



On rare occasions a green flash can be seen for a few seconds just before the sun sets. Anthony Hewish, the discoverer of Pulsars, confirmed to us that he had himself seen this rare and striking phenomenon. Any idea what could cause such a phenomenon?

## Hotter Freezes Faster



In cold countries like Canada and Iceland it is known that water left in the open during winter freezes faster if it is initially heated to a higher temperature. Isn't that counter-intuitive? Francis Bacon had noticed this strange phenomenon and commented on it. Recently G. S. Kell (National Research Council, Canada) made a systematic study of the phenomenon (*American Journal of Physics*, Vol.37, p.564). He points out that the effect is more pronounced if one uses wooden rather than metallic vessels without lids. If you are sceptical, try the following experiment. Heat some water and pour it into a wooden or plastic vessel without a lid. Take the same amount of water at room temperature in a similar vessel, and put them both into the deep freeze of your refrigerator. Which one freezes first and why?

Remark : We would only like to point out one important factor - water at a higher temperature loses mass at a faster rate due to faster evaporation, than colder water. Hence, if you start with the same mass, by the time the temperature is equalized, the hotter water has lost more mass and so has a lower heat capacity (mass times specific heat). So it cools down faster subsequently. It would be, of course, very interesting to make a quantitative study of the relative importance of the various other factors involved, such as the effect of convection currents, the difference in the conductivities of vessels, etc.

## The Blue Mountains



While travelling in hilly terrains, do you ever wonder why distant mountains often look blue?

## The Receding Blue



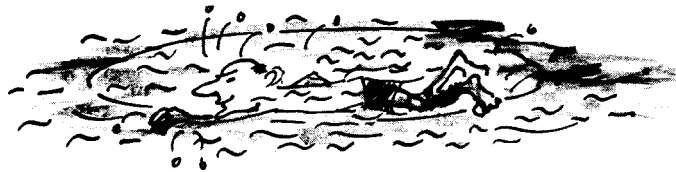
If you stand on a beach and look out into the sea, you will often find that there is a sharp line near the horizon beyond which the sea looks distinctly more blue. If there is a cliff nearby and you start climbing it, you will find that this line of demarcation appears to recede towards the horizon. Why? This problem was suggested to us by Dr. Andrew Whitaker (Queen's University of Belfast, Northern Ireland).

## The Tumbling Can



One day Richard Feynman came into the kitchen where John Wheeler's wife was cooking dinner. He took off the counter an unopened tin can, and said to the children: "I can tell you whether what's inside is solid or liquid without even opening it or looking at the label. Do you know how?" "How?" asked the incredulous children. Feynman tossed it up and watched it turn and wobble. "Liquid", he announced. He was indeed found to be right on opening the can. What was the 'trick' he used?

## Swimming in Circles



Richard Feynman was one day chatting with a group of swimmers. He heard them say that it helps to swim faster if one shaves one's legs and is nearly bald. Feynman was curious to verify whether this was indeed true. He suggested an ingenious way of testing it: if a swimmer shaves just one of his/her legs, he/she should swim in circles if shaving does indeed help to swim faster. What do you think?

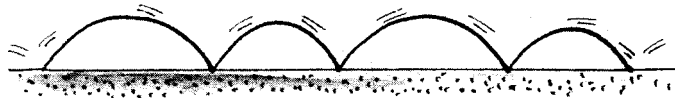
## The Impending Storm



Have you observed that a cloudy night sky sometimes takes on a faint reddish glow before a storm? What do you think is the reason?

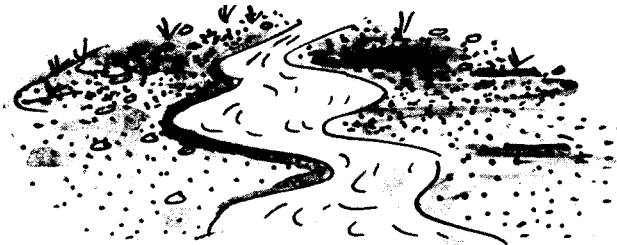


## Hop Along



Have you ever skipped a stone on water? If you have, you would have noticed that it bounces in a series of successively shorter leaps before stopping and sinking. However, Professor E.H. Wright of Columbia University hit upon the ingenious idea of skipping a stone on hard-packed, wet sand on a sea beach, and he discovered a queer phenomenon. The first bounce of the stone was short, the next a little longer, and then strangely, this short-long sequence repeated itself (periodic behaviour) until the stone came to rest. This behaviour has been found to occur with all stones of a regular shape. Careful, detailed studies have been made since Wright's initial observation, including the use of high speed photography. We find all attempts so far to explain it rather complicated. We would like to have a simple qualitative understanding of it. Perhaps you can help?

## Meandering Rivers

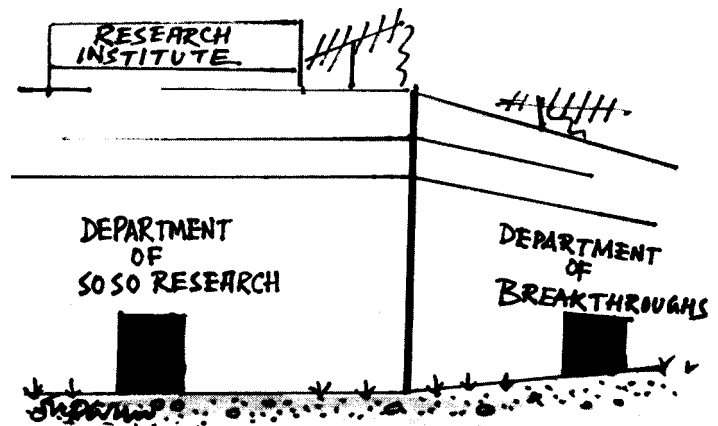


Rivers are found to meander rather than flow straight. Even someone like Einstein was puzzled by this and wrote an essay on the subject. He noticed that there was a connection between the formation of meanders and “the tea cup phenomenon” (see Chapter 1). What is the connection?

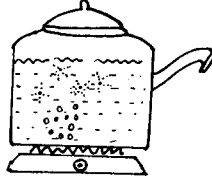
Remark : It's essentially the secondary flow phenomenon (see answer to “Einstein in Your Teacup”, Chapter 1) that is responsible for the formation of meanders. The river bed acts like the sides of a teacup. In a river, of course, the water flows along the channel. The river bed retards the flow along the bottom and the sides. As a result the water along the centre and near the surface flows faster than the rest. This sets up the secondary flow which now occurs helically downstream. When the river meets with an obstacle like, e.g., a hard rock on its right bank, it is deflected to the left. The secondary flow then keeps eroding the left bank and taking the debris and depositing it on the right bank a little further downstream. This makes the river turn to the left until it meets with another obstacle. Only the meandering would then seem to require that the river meets with these obstacles quite randomly on its left and right. Although this is plausible, an element of doubt still remains. The actual explanation requires a more detailed enquiry.

## Tap Dancing

Turn on the tap and close it slowly until you get a very thin but steady flow of water through the faucet. Place your finger in the stream and a standing wave like pattern appears. Note that the periodicity in the pattern depends on the distance between your finger and the faucet. We do not know of any convincing explanation of this intriguing effect. Can you help?



## ANSWERS

**Kettle Croon**

It is the bottom layer of water in the kettle that gets heated first. As the temperature rises, steam bubbles (not air bubbles) form at the bottom. Being lighter than water, they rise and come in contact with the cooler layers of water above, contract, and eventually collapse. It is the collapse of a myriad steam bubbles that produces the hissing sound. The sound, therefore, increases as more and more steam bubbles form and collapse. Eventually, however, when the entire mass of water is heated to the boiling point, the steam bubbles do not collapse any more because they no longer encounter cooler layers of water. The hissing therefore ceases, and the whole mass of water in the kettle starts boiling.

**Spoon in a Teacup**

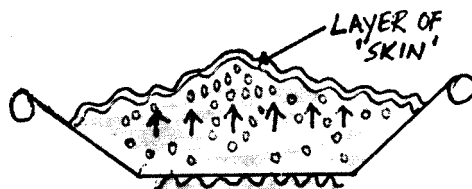
A good housewife puts in a metal spoon because metals are good conductors of heat. Can you work out the rest? When hot tea is poured into a cup, first the inner layers of the walls heat up and then gradually the outer layers. This uneven heating leads to uneven expansion and the cup cracks. Thick walls will therefore crack more easily than thin ones.

**Don't Lick an Ice Tray**

There is always some moisture on your fingers. When you touch the frosted sides of the ice tray, this moisture freezes and the pressure of your fingers makes the frozen moisture stick to the ice crystals on the tray. If you try to lick the tray, your tongue will stick to it and a layer of the skin may be ripped off.

**Frying Food and Fermi**

The answer lies in the simple fact that when food is fried, it is not the oil that boils but the water in the food, and of course the boiling point of water is lower than the melting point of tin!

**Leaping Liquid**

Everyone knows that a layer of “skin” forms on the surface of milk when it is heated. This is because some of the fat in the milk separates. All the steam bubbles formed within the milk (milk contains a lot of water) get trapped by this skin. It is the pressure of the trapped steam that eventually raises the skin and makes some of the milk spill. The stirring breaks the “skin”, releases the pressure and prevents the spillover. The housewife has discovered this technique through trial and error.

## Soup Swirl



Soup flow reversal is a simple illustration of “visco-elasticity”. (An “ideal” fluid has no viscosity but all “real” fluids are viscous.) Once you stop swirling the soup, the layers in contact with the bowl come to rest because of friction. However, the top layers of the soup that are not in contact with the bowl continue to move, because real fluids are viscous. The stationary layers in contact with the bowl exert a visco-elastic restoring force on the moving layers which therefore slowdown and eventually reverse their direction of motion. An oscillatory behaviour sets in, analogous to the oscillations of a spring which is stretched and released. These oscillations are eventually damped out by the soup’s viscosity. If one is dealing with a fluid which is highly viscous, such as a paste, the oscillations can be damped to such an extent that only one reversal occurs.

## The Kitchen Sink

The physics behind this common phenomenon involves the propagation of waves (controlled by gravity) on a moving stream of water. The crucial feature is governed by a quantity called the Froude number which is the ratio of the stream speed to the wave speed. Gravity waves on water surfaces can propagate only if this Froude number is less than unity. It so happens that the speed of gravity waves increases with the depth of water. At the point of striking the sink, the water speed is sufficiently high and it spreads out quickly into a thin sheet. The Froude number in this region is greater than unity. However, friction inevitably slows down the water and inhibits its quick dispersal. Consequently, the water depth starts increasing with distance. Eventually it reaches a critical value beyond which the Froude number decreases below unity and gravity waves start propagating. This is where the water wall forms rather abruptly. The greater the speed of flow from the tap, the larger is the radius of the water wall. The effect is more pronounced in a sink with a curved bottom because of the back flow of water due to gravity. If you plug the sink and allow the water to accumulate, you will find that the radius of the wall gradually decreases and it eventually disappears altogether.

## Honey of a Problem

We know that the surface of liquids behaves like a stretched membrane and stores energy. This energy per unit area of the surface is in fact a measure of the surface tension which tends to reduce the surface area to a minimum. When the weight of the accumulated honey exceeds the pull of surface tension, it lengthens and comes down. The slicing reduces the weight of the honey above the knife. If the slicing is not done too far down from the mouth of the pot, the surface tension is sufficient to overcome the pull of gravity.

We have tested this by watching drops of water fall from the mouth of a slightly open tap. We have found that water drops too lengthen as water accumulates at the mouth of the tap. As the drops get bigger, they become more and more elongated and eventually break off from the tap and the remaining water shrinks back.

## Einstein in Your Teacup



In the words of Einstein himself: ‘The rotation of the liquid causes a centrifugal force to act on it. This in itself would give rise to no change in the flow of the liquid if the latter rotated like a solid body. But in the neighbourhood of the walls of the cup the liquid is restrained by friction, so that the angular velocity with which it rotates is less than in other places nearer the centre. In particular, the angular velocity of rotation, and therefore the centrifugal force, will be smaller near the bottom than higher up. The result of this will be a circular movement of the liquid of the type, which goes on increasing until, under the influence of ground friction, it becomes stationary. The tea leaves are swept into the centre by the circular movement and act as proof of its existence’.

You must have noticed that the tea surface looks like a curved surface turned upwards when the tea rotates. In this condition the flow referred to by Einstein (called the “secondary flow”) acts in a direction that drives the tea leaves away from the centre. When you withdraw the spoon and let the tea slow down, the surface begins to flatten and the direction of the “secondary flow” reverses, bringing the tea leaves to the centre of the bottom.

## 2

### Have a Drink

When we drink, we first expand our chest with the help of our lungs. This expansion rarefies the air inside our mouth. Its pressure falls and the atmospheric pressure outside forces the drink to enter into this region of lower pressure.

If you cover the mouth of a bottle containing a drink with your lips, you cannot suck in the drink because the pressure above the drink and inside your mouth is the same. You have to raise the bottle above your mouth and turn it upside down. Gravity then makes the drink flow down into your mouth.

### Soap and Dirt

Dirt particles are of two types, oily and charged ones. Simply washing with water does not remove them because they tend to cling to our bodies and clothes. To make matters worse, oil does not mix with water. Soap molecules have the characteristic property (from their molecular structure) that they tend to get attached to oily and charged dirt particles. Subsequent washing with water then removes the dirt with the soap from the clothes.

### The Burning Flame

Contrary to expectations, the protected flame will move forwards, not backwards! This is because the flame, being hotter, is lighter than the surrounding air. Now, when a force is applied to a body, it moves faster, the smaller its mass. (This is Newton’s second law of motion.) Being lighter, the flame moves faster than the surrounding air and is therefore seen to be deflected forwards.

### Funny Funnel

As the liquid enters the bottle, it starts squeezing the air in it which cannot escape. This goes on until the air pressure in the bottle is high enough to hold up the weight of the liquid in the funnel. You must then lift the funnel a little to let the compressed air escape. Then the liquid starts flowing down again.

## Blow Out!

Newton's laws of cooling (not motion) are at work here. One of these laws says that the larger the difference between the temperature of a hot substance and its surroundings, the more rapidly it cools down. This is why, for example, our tea cools down quicker in winter. Also, when we blow over hot tea or milk to cool it quickly, we replace the hot air that accumulates over it by cooler air, and this helps more rapid cooling. There is another law of Newton which says that the larger the surface area of a hot substance, the more rapidly it cools. This is why pouring tea into the saucer helps to cool it faster. Both these laws operate in the case of the candle and cools the burning wax vapour below its ignition point (the temperature below which wax vapour does not burn). When we blow air at a candle flame, we (a) replace the hot air surrounding the flame by cooler air, and (b) we distort the spherical shape of the burning wax vapour (not the flame, which is not spherical) and increase its surface area. Simple geometry shows that for a given volume of a substance, the spherical shape has the least surface area. Any distortion from the spherical shape therefore increases the surface area of the substance. Contrary to what you might expect, it is actually possible to ignite coal or strip off paint by a jet of sufficiently hot air. Such contraptions (called 'hot air strippers' or pokers) are now commercially available abroad.

## Iron it Softly

The starch in the cloth goes into solution when water is sprinkled on it. This helps to soften the cloth. A hot iron is useful because the heat helps to evaporate the water quickly, leaving a stiffened flat surface.

## Fire! Fire!

There are two factors which make water a good fire extinguisher. First, water absorbs a large quantity of heat from the burning object (we say, its specific heat is high), and helps to cool it. Secondly, the steam formed as the water boils in contact with the burning objects occupies a very large volume and envelops the burning object, shutting off the oxygen supply. As you know, nothing can burn in the absence of oxygen.

## Ice Fumes

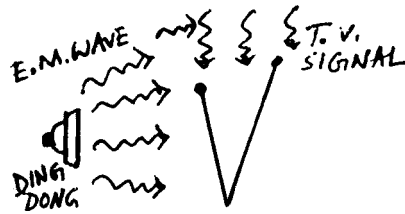
When a large slab of ice is kept in the open, it gives out dense fumes. They are not fumes of any gas but simply water vapour that condenses in the cool air surrounding the ice. When the air surrounding the ice becomes very cold, some of the water vapour present in it condenses into tiny droplets of water. The condensed vapour looks like fumes when it moves up and down with the convection currents of air.

## Coasting Along

The following points are worth noting :

- (a) The first point is that your hand holds the glass with the drink in it. The weight of the glass is therefore balanced and does not come into the picture.
- (b) The thin layer of water between the bottom of the glass and the upper surface of the coaster removes all air from this region. Therefore the only pressure that acts downwards on the coaster comes from this layer of water. In order that the coaster gets lifted, the sum of the weights of this layer of water and the coaster must be less than the thrust of the atmosphere acting upwards on the bottom of the coaster. No wonder heavy coasters do not get lifted.
- (c) The upper surface of the coaster must be fairly smooth so that no air bubbles can get trapped.

## Of Doorbells and TV Screens



Whenever you press the door bell switch, an electric current flows to activate the bell. The current is carried by accelerated charges which emit electromagnetic waves. (Such waves, predicted by James Clerk Maxwell in the nineteenth century on the basis of his theory of electromagnetic phenomena, travel through empty space with the velocity of light. In fact, light is a form of electromagnetic wave.) These waves interfere with the normal TV signals which are also electromagnetic waves and give rise to the disturbances on the TV screen. Next time you see such disturbances, think of Maxwell and his equations.

## Tractors and Buffaloes

The answer lies in the difference between weight and pressure. Although the tractor is much heavier than the farmer or his buffaloes, its weight is distributed over a much larger area of its bottom surface. Consequently, the load carried by each square centimetre of its bottom surface (the “pressure”) is fairly low. On the other hand, the weight of the farmer or his buffaloes is concentrated over the much smaller area of his feet or the hooves, producing a much higher “pressure”. An object penetrates deeper not because it is heavier but because it exerts a higher pressure (force per unit area) on its support.

## Dropping a Bottle

Since it is safer to jump off a moving bus or train facing the direction of motion, you might think that the bottle should be thrown forwards. You are wrong. It should be thrown backwards, because its velocity of projection would then be opposite to its inertial velocity (the velocity of the bus or train) with the result that it will strike the ground with a smaller impact. If you throw it forward, its velocity of projection will add up with its inertial velocity and it will strike the ground harder.

Why then is it safer for us to jump from a moving bus and run forward? The answer is that we then avoid falling flat on the ground and injuring ourselves.

## Swimming Underwater

When we swim underwater, a layer of water covers the surface of our eyes. The refractive index of water is approximately the same as that of the substance of our eye lens. Hence no appreciable refraction can occur when light enters our eyes from the water. Consequently, no sharp images are formed on our retina and we cannot see properly. But if we wear goggles, then a layer of air is trapped between the water and our eyes. Air has an appreciably different refractive index from the material of our eye lens. This enables light rays to refract when entering into our eyes and helps us see much better.

## Blinding Light

The human retina contains two types of light sensitive photo receptor cells called “rod cells” and “cone cells”. Rod cells are adapted to sensing low light intensities but not colours and are involved in night vision. Cone cells are adapted to high light intensities and can sense colours. When light falls on the retina, the light energy is absorbed by a pigment (a protein called “rhodopsin”, earlier called “visual purple”) in the photo receptor cells to yield a specific photochemical product which initiates the nerve impulses to our brain. The “visual cycle” is completed when the light sensitive form of the visual pigment is regenerated. We can adjust our eyes to a certain incident light intensity by opening or closing the eyelids and controlling the amount of light that falls on the retina so that there is a balance between the amount of pigment that is bleached by light and the amount that is regenerated. If the incident light intensity changes suddenly, this balance is disturbed, resulting in a temporary loss of vision until a new balance is achieved. If the incident light is too bright, we have to close our eyes altogether.

## Hum with Your TV

When a person hums a particular pitch or frequency, his eyeballs start vibrating with the same frequency. How this occurs was first analysed in detail by W.A.H. Rushton (Physiological Laboratory, University of Cambridge) in an article published in the prestigious science journal, (*Nature*, Vol. 216, pp. 1173-1175). He gave a physiological explanation of how humming affects the brain, and he suggested several experiments to demonstrate the effect. Television pictures are formed by the recurrent line by line horizontal scanning by an electron beam which excites the screen. The frequency with which the electron beam sweeps the screen from top to bottom is so high that the recurring images appear continuous to our eyes. If a viewer hums with the same frequency, his eyes start opening and closing with that frequency, producing a stroboscopic image of the screen on his retina. In other words, the image freezes on the retina. If he hums with a frequency too high or too low, the image will appear to move upwards or downwards. Obviously, the effect is only visible to the viewer who hums.

## Coiling Chocolate

The clues lie in the low surface tension, high adhesivity and high viscosity of thick molten chocolate. The first two make it fall in a continuous stream without breaking into drops. The high viscosity prevents it from spreading too quickly on the plate after falling. This makes the initial bit of falling chocolate accumulate in a small heap which tends to keep its shape for a while. Subsequent streams of chocolate form distinct layers, one above the other, and these also retain their identities for a while before merging into a single heap. It is the formation of these distinct layers, one on top of the other, that is responsible for the coiling. Incidentally, the same effect is seen with shampoos.

## Rest in a Hammock

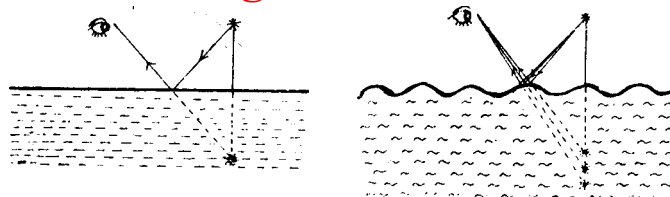
When you sit on a flat-topped stool, your weight presses down on a small area. A chair usually has a concave seat which helps to spread out your weight over a larger area. In other words, you exert less pressure per unit area. When we lie on a soft bed, we make depressions that conform to the uneven shape of our body. Our weight is therefore more uniformly distributed, decreasing the pressure everywhere. This is why we feel so comfortable lying in a hammock or on a soft bed.

## Play on a Ship

Neither has any advantage if the ship moves steadily in a straight line. You might think that the person standing nearer the bows recedes from the ball after it is thrown and the other person moves forward to receive it. A little reflection will show that this is not true. The ball as well as the two friends are carried by the ship and therefore have the same speed as the ship. This is called their inertia! speed. Therefore the ship's motion (as long as it is steady and in a straight line) cannot give any one of them an advantage over the other.

In fact, to all passengers on board such a ship everything would proceed as if the ship were at rest and the water and the shore were moving in the opposite direction. There is no physical way of distinguishing uniform velocity from rest. Uniform velocity is purely relative. Believe it or not, this is the famous principle of relativity.

## Long and Broken

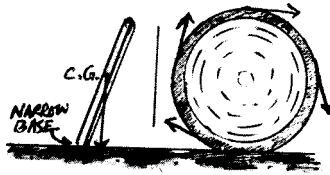


When the surface of a lake or pond is undisturbed, it behaves like a plane horizontal mirror. The laws of reflection of light (angle of incidence equals angle of reflection) operate and only the light (from a point source on the opposite bank) reflected from a particular point of the surface can enter our eyes. This ensures that we see a clear image of the light source. However, when the surface becomes wavy due to the action of the wind, there are multiple points on it that are so inclined relative to us that they can all reflect the light into our eyes, and we see multiple images. As the waves move, these points also change and the images keep shifting.

## Boot Polish

Polishing is such a mundane affair that we never bother to stop and think about it. Yet the answer is not obvious. The surface of leather is full of hills and dales and fine hair. The dimensions of these irregularities are of the order of the wavelength of light. Light can therefore “see” them and get scattered in all sorts of directions. This makes the surface look dull. The effect of the polish and the brushing is to even out the irregularities and make the surface “look” flat to light. The laws of reflection then make the surface look like a mirror.

## Ride Along



The answer lies in a principle of mechanics called the conservation of angular momentum. A cycle at rest is unstable because its base (the tyres) is narrow and its centre of gravity is fairly high above the ground. So a little tilt makes the vertical line through the centre of gravity fall outside its base and it topples. When you give it a rolling motion, its wheels acquire a rotatory motion. The material particles making up the wheel all have a tendency to fly off tangentially in the plane of the two wheels. In the absence of friction, the law of inertia would keep them moving in the plane. Consequently, the moving wheels tend to maintain their orientation in space. This gives them stability against falling. Once their speed decreases due to friction, they start wobbling and eventually fall.

## Whistle Melodies

Whistling is produced by what is called a “hole tone” effect. When air passes through a hole with sufficient speed, vortices are formed and these produce the sound.

The tea kettle whistle is another familiar example of the “hole tone”. Such a whistle consists of two holes separated by a small cavity. When the stream of air from one end impinges on the other hole, vortices form which create a sound wave. The air in the second hole vibrates like the diaphragm of a loud speaker. For further details, you might like to read the article by R.C. Chanaud in *Scientific American*, Volume 222, pp. 40-46. Have you ever tried whistling under water? Is it possible?

## Tear a Paper

Paper is made of cellulose fibres. When you tear a piece of paper, these fibres snap one after another and set off vibrations in the paper which produce sound waves in the surrounding air. When you tear it up quickly, you snap a larger number of these fibres in a given time and so increase the frequency of vibrations and hence the pitch of the sound.

## Woof, It's Cold !

The temperature drops with height because of two factors: (a) Although air absorbs all the dangerous rays from the sun (like ultra-violet, X-rays, etc.), it does not absorb the sun's heat very much. It's the earth's surface (and our skin) which absorbs the sun's heat and warms the adjoining layers of air by convection, (b) However, the density of air and its pressure decrease with height, and as a result, the air warmed by the earth expands and cools as it rises. Consequently, it cannot rise very far and is trapped near the earth's surface below the cooler layers above!

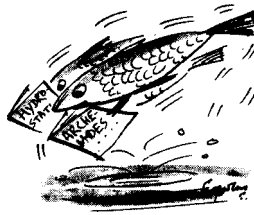


## The Foggy Mirror

The answer is quite simple. Put a bit of soap or detergent on the mirror (or the inside of the wind screen of your car during a heavy shower). A fresh slice of potato will also do. Now, what's really going on? It's all to do with surface tension and the angle of contact (the angle that a liquid drop makes with the surface on which it rests). No matter how clean you think your bathroom mirror is, it is, in fact, quite filthy. This is why the water that condenses on it cannot spread and wet it. Instead, it collects as small droplets. In other words, the contamination increases the angle of contact between the mirror and the water. No matter how hard you try, you are unlikely to be able to remove the filth, because even minute traces of it will affect the angle of contact. You can, however, use a thin coating of some liquid to reduce this angle. Detergents and the fresh juice from a potato do this trick. Without them, the minute droplets scatter light in all directions. This diffuse scattering results in the fogging.

## Roll a Coin

When we place a coin vertically on its edge on a table, it is unstable because its base area is small and a slight tilt makes the vertical line through its centres of gravity fall outside its base. It is similar to tight-rope walking. When we give it a push, we make it roll and it acquires angular motion about an axis passing through its centre and perpendicular to its plane. Just as linear motion has inertia, angular motion too has inertia. If no external force acts on the coin tending to change its rotational state, it would continue to roll forever. (This is technically known as the 'conservation of angular momentum')- In practice, however, there is always some frictional force between the table and the coin, which slows it down and it eventually topples. But before toppling, it curves to the right or left. There is an interesting feature here. The turning of the coin to the right or left is, in practice, unpredictable, though its behaviour is, in principle, deterministic, i.e., governed by causal laws of motion. There are so many unknown and uncontrollable factors that can affect its motion (for example, slight defects along the edge of the coin, unevenness of the table, fluctuations in the breeze, sudden vibrations of the table and so on) that it is impossible to foresee them and take them fully into account. The moral is: determinism does not necessarily imply predictability in practice.

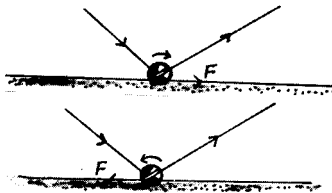


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## Raman's Billiard Ball Problem

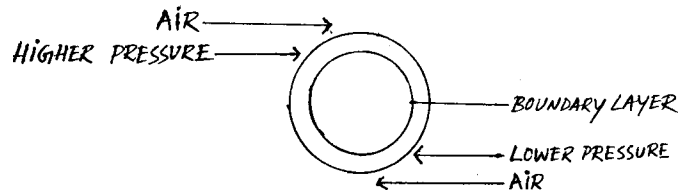
The answer is surprising - it is the backward direction, i.e., the direction from which the striker ball comes. The reason is that the striker ball drags the air around it. When it strikes the target ball, it stops momentarily. This makes the air trailing behind it get suddenly compressed and produces a kind of shock wave with its intensity peaked backwards,

## Play Cricket



When a bowler delivers a ball, usually a spin is imparted to the ball. When a ball with a spin axis perpendicular to the vertical plane in which it moves, hits the ground (pitching), there is some friction between the surface of the ball and the pitch (ground). On a smooth pitch this force of friction is just sufficient to convert some of the rotational kinetic energy into translational energy. This makes the ball move faster after pitching but with a lower value of spin. As shown in the diagrams, the frictional force reduces the spin when it is clockwise as well as when it is anti-clockwise. Consequently, the linear speed always increases.

## Top Spin



The essential point is this. When the ball spins, it carries with it a thin layer of air (boundary layer) which sticks to it. This causes a difference between the velocities of air flow at the top and bottom of the ball (see figure) and consequently a difference in pressure (Bernoulli's theorem). In order to make the ball dip, it is necessary to create a higher pressure and therefore a lower relative air velocity on the top. This can be ensured by making the ball spin forward relative to its direction of motion. This is an example of the Magnus effect in hydrodynamics.

## Follow Shots

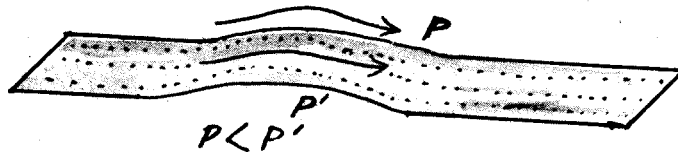
Although the translational kinetic energy of the cue ball is transferred to the other ball, it retains its rotational kinetic energy. It therefore continues to rotate after the collision, slips for a brief while and eventually rolls forward because of the friction between it and the table. Energy is therefore still conserved, except for the effects of friction.

## 4

## Smoky Swirls

The hot gases (smoke) from the burning cigarette first rise slowly and have a laminar flow. They then accelerate because of the buoyant force exerted on them by the cooler surrounding air. After a few centimetres the velocity is high enough for turbulence to set in, and eddies form.

## The Fluttering Flag

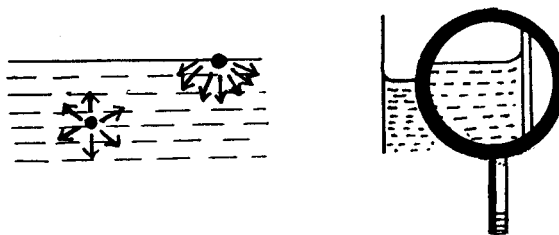


Imagine the flag perfectly flat and fully spread out in a strong wind. Suppose a small disturbance develops in one part of the flag that causes a ripple in it. The air stream flowing across the flag must speed up as it crosses over the ripple. The faster moving air has less (sideways) pressure (Bernoulli's principle) and hence there is a difference in air pressure on the two sides of the flag near the ripple. This happens randomly all over the flag. It is these pressure differences that cause the flag to flutter in the wind.

## The Puzzling Balloons

The explanation hinges on the “Archimedes principle” and “pseudo-forces”. A helium-filled balloon experiences an upward buoyant force equal to the weight of the air it displaces (Archimedes principle). Since helium is less dense than air, this buoyant force is greater than the balloon’s weight. It therefore floats upwards against gravity. Now, when a car accelerates, say in the forward direction, a backward force is generated on massive bodies inside it because of their inertia of rest. When a car brakes, the inertia of motion produces a forward force inside it. Such purely inertial forces which originate in the use of accelerated frames of reference, such as an accelerated car, are called “pseudo-forces” to distinguish them from “impressed forces”. Unlike “impressed forces”, “pseudo forces” do not arise from the proximity of other physical bodies and do not fall off with distance. These horizontal forward and backward pseudo-forces inside the car play the role of gravity, and the helium-filled balloons move against them because of the buoyant force resulting from the Archimedes principle.

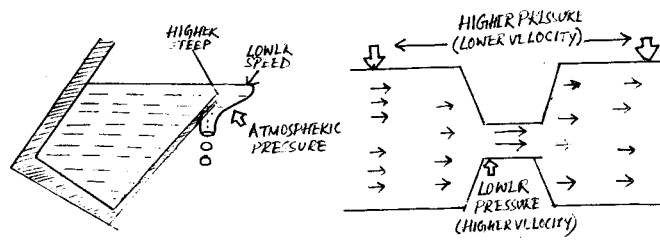
## An Anti-gravity Effect



The source of energy in capillarity is called “surface tension”. It is the energy that resides per unit area of the surface of a liquid. The neighbouring molecules of a liquid attract one another. Since a molecule well inside a liquid is surrounded on all sides by similar molecules, it is pulled equally in all directions. Consequently, it does not feel any resultant pull in any direction. But think of the molecules near the surface. They have no similar molecules above them. As a result, the downward pull of the molecules below them remains unbalanced. This net downward force on the surface molecules is called “surface tension”. If you want to take out a molecule from the surface, you will have to spend some energy to overcome this surface tension. This force makes the surface of a liquid behave like a stretched elastic membrane tending to shrink as much as possible. This is why in the absence of gravity, a liquid will always take the form of a sphere, because for a given volume, a sphere has the minimum surface area. Small quantities of water therefore form drops. This is also why the water surface curves upward whenever it comes into contact with the side of the glass, making a definite angle called the “the angle of contact”. On the other hand, the surface of mercury which does not wet glass, curves downward wherever it touches the glass. When a capillary glass tube is inserted into water, its bore is so narrow that the angle of contact between water and glass cannot be maintained inside it, and the surface tension pushes the water up the tube until gravity balances it.

## Pour a Liquid

Believe it or not, it is atmospheric pressure in conjunction with what is known as the Bernoulli principle that makes a liquid stick and run down the side of its container. The Bernoulli principle is a very general principle of fluid flows and has numerous applications. It says that when a more or less incompressible fluid flows, its pressure decreases wherever it flows faster and vice versa. This is a consequence of the fact that energy can neither be created nor destroyed (the famous principle of the conservation of energy). Imagine spectators crowding in the foyer of a cinema hall after a show. If you are in the foyer you feel everyone pressing against you, and you move slowly towards the exit. When you come close to the exit, however, you start moving quicker and the pressure on you drops. This is because pressure is generated by the sideways pushes of people around you. When everyone moves forward, this pressure drops. The same is true of the molecules of a liquid. When they move slowly, they jostle and collide against one another and the walls of the container, creating a pressure. When they approach a narrower section of the tube, they move forward faster because, being incompressible, the same amount of fluid has to pass through the narrower sections in the same time. The pressure consequently drops.



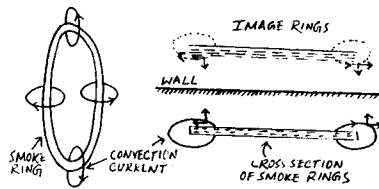
When you pour a liquid out of a thin container, the bottom layer of the stream in contact with the edge of the container turns round much faster than the top layer. According to the Bernoulli principle, therefore, there is a pressure drop across the width of the stream, and the atmosphere presses the stream against the container edge.

If you pour out the liquid fast by turning the can quickly, the stream acquires an overall velocity, there is no longer any appreciable pressure drop across the width, and the liquid does not stick.

## The Tapering Stream

There is no force that squeezes the water stream and makes it narrower as it falls. It is the conservation of mass at work. Since water is incompressible, the same mass or equivalently the same volume of water must pass through every horizontal slice (cross-section) of the stream per second. Since water speeds up as it falls, more water would pass through successive cross-sections per second unless the cross-sectional area decreases. You may say it is gravity pulling on the water that is responsible for the narrowing of the stream.

## The Expanding Smoke Ring



Let us first see why smoke rings are stable far away from walls. The hot smoke ring {in a vertical plane} sets into motion convection currents in the surrounding air which thread the ring as shown in the figure. Since there is no preferred direction in the space surrounding the smoke ring, convection currents flow symmetrically all round it. The ring, therefore, experiences equal pushes and pulls from every direction. The net effect is nil, and the ring is stable. However, as it approaches a wall, the convection currents strike the wall. Since the layer of air in contact with the wall is always at rest (viscosity), the presence of the wall affects the convection currents which can no longer flow symmetrically around the ring. The proximity of the wall spoils the isotropy of the space surrounding the ring. The components of motion perpendicular to the wall get cancelled, while those parallel to it get reinforced. Consequently, the ring expands. The delicate interplay between symmetry and dynamics in such a common phenomenon is indeed fascinating.



## Through the Palm, Strangely!

When we look at an object, both our eyes get focused on it automatically even when we keep one of them closed. This is called “sympathetic focusing or adaptation” of the eyes. In the experiment concerned, your left eye is focused on a distant object. In sympathy, your right eye also gets focused on it, although it is closed. When you bring your right palm in front of it and open your right eye, your palm appears blurred or de-focused. In other words, your left eye sees the distant object clearly through the tube while your right eye does not see the right palm clearly. This gives you the impression that you are seeing the distant object through a hole in your right palm. In order to verify this, do the experiment again and try deliberately to look at your right palm. The moment you concentrate on it, the palm will come clearly into view and the distant object and the hole in the palm will disappear.

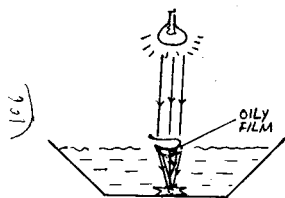
## It Does Not Pour Out

There is always a tendency for the water to flow out of the glass through the space between the rim of the glass and the stiff card. To observe this, use a thin metal in place of the card and press it against the inverted glass. You will see a thin layer of water bulging and skirting the glass rim. The moment you release the pressure on the plate, you will notice that this water will disappear into the glass and the plate drops a little. This is enough to make the air above the water expand and make its pressure drop sufficiently so that the atmospheric pressure is able to hold the card with the water above it. To test that the air above the water does indeed exert less pressure than the atmosphere, you can make a hole in the bottom of the glass and fix a glass tube through it so that one end of it is in the space above the water. Do the experiment with the other end of the tube closed with a finger. As soon as you remove the finger, the card will drop.

## Darting Pepper

The answer lies in the surface tension of water. You would recall that the surface of water behaves like a stretched rubber membrane and this helps pondskaters to move about on the surface of ponds without sinking. Well, soap lowers the surface tension of water. So, when you put a little detergent soap on the water surface, its surface tension is lowered locally. This is like making a hole on the surface of a stretched membrane - the punctured membrane shrinks, carrying the pepper with it.

## The Silvery Shadow

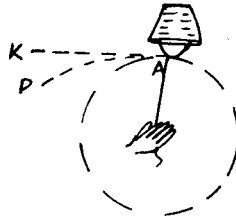


The splitting and silvery linings are caused by the refraction of light by the curved surface of water around the fingertip or legs of an insect. Usually our fingers and insect legs are covered by an oily film. Since oil and water do not mix, our fingers and insect legs make a dent on the water surface which acts like a stretched membrane (surface tension). The curved water surface acts like a lens which focuses the incident light along the edge of the shadow.

## Weigh Yourself

When you bend forward, the muscles that help you do that pull up the lower half of your body. This is why your body exerts a lower pressure on the weighing machine. When you lift up an arm, the muscles used to do this push down on your shoulder and increase the pressure on the weighing machine. Of course, your mass does not change at all. It is Newton's third law that operates. The sudden motion (or strictly speaking, the momentum) of your hand upward must be balanced by an opposite movement downward.

## Defying Gravity



Usually people say it is the 'centrifugal force' on the rotating water that is responsible for its tendency to fly outward and thus prevent it from spilling out when the bucket is bottoms up. This is not correct. In the absence of gravity the water in the rotating bucket would tend to fly off tangentially (parallel to the horizontal path AK in the diagram) due to its inertia of motion (Newton's first law). Gravity would, of course, bend it parallel to the parabolic path AP if unobstructed by the bucket. So the water does not at all seek to fall vertically. The "centrifugal force" that physicists talk about does not act on the water but on the rope attached to the bucket. It is the rope held by your hand which prevents the bucket from flying off tangentially and develops a tension which is balanced by your hand. Your hand therefore feels this force. So this force does not act on the moving body but on the obstacle that prevents it from moving in a straight line - the string.

## Weigh a Stone in Water

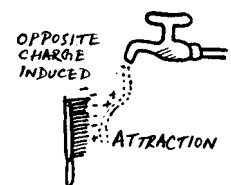
The balance is maintained. This is because, although the stone should weigh less in water than in air because of the greater upthrust the water exerts on it, it will also displace its own volume of water whose level will rise. The water will then exert an additional force on the bottom of the glass exactly equal to the weight lost by the stone - an illustration of the famous Archimedes principle.

## The Puzzling Rubber Band

Note that the quick stretching of the rubber band is an "adiabatic" process in which no exchange of heat with the surroundings can occur, and the work done by us in stretching the rubber band goes entirely to increase its internal energy. This raises the temperature of the rubber band. On the other hand, when a gas expands rapidly, the gas itself has to do work against attractive intermolecular forces, and it draws the required energy from its own store of internal energy. Consequently, the gas cools down.

## Comb Your Hair

When you comb your hair or rub the comb with a piece of flannel, the comb is weakly electrified. The proximity of the comb induces an opposite electric charge on water molecules. The comb and the water therefore exert an electrical force on each other. Since you hold the comb steady, it is the water that gets deflected. The trickle becomes a steady stream because of the change in the surface tension of water as a result of electrification.



## **The Woolly Winter Coat**

The reading of the thermometer will be exactly the same as before, because the coat does not warm it, nor does the thermometer generate heat. However, the ice cube wrapped up in the coat hardly melts. Both these effects show that the coat is a bad conductor of heat; it prevents heat from flowing across it either way. This is why it helps to keep us warm. Our bodies generate heat which it prevents from escaping into the surrounding air.

## **The Paper Kettle**

The reason is that in an uncovered pot you can only heat water up to its boiling point, i.e., 100 deg. C. Water has a great capacity to absorb heat. It absorbs the heat that would have otherwise burnt the paper. In other words, it prevents the paper from being heated to a point where it would catch fire.

## **The Jumping Draught**

You must have noticed that when a moving ball is made to hit an identical ball that is stationary, the moving ball stops and the target ball rolls forward with its velocity. This is an example of an impact. In this case the impact occurs between two elastic bodies. An impact lasts a split second. During this short time, however, a whole process occurs. First, the two bodies compress each other at the point of contact. Internal restoring forces are generated by this compression. When the compression reaches its maximum, these internal forces begin to push the bodies out in opposite directions and restore their shape. The moving ball is stopped by these restoring forces and its velocity is transferred to the target ball. We may say that the impact is, as it were, transferred from the first to the second ball. This is an example of two fundamental laws of mechanics - the conservation of energy (which states that energy can neither be created nor destroyed) and the conservation of momentum (mass x velocity). Exactly the same thing happens with the draughts or coins. The impact is transferred from the first draught through the intermediate ones to the last one which has no other draught to transfer it to - so it moves away.

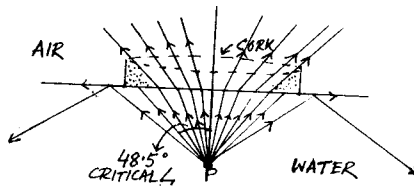
## **Which is Heavier?**

The two glasses will weigh the same. This is because the floating piece of wood displaces exactly its own weight of water, and so, although the glass with the piece of wood has less water in it than the other glass, the weight of the piece of wood exactly balances this loss. This is the Archimedes principle again.

## **Tearing Wet Paper**

It is the adhesive force between the cellulose fibres of which paper is made that must be overcome in tearing paper. In the presence of water this adhesive force which is of electrostatic origin is weakened, much the same way as when solubles like salt (e.g., sodium chloride) dissolve in water because of the weakening of the electrostatic attraction between the positively and negatively charged ions. In the case of paper the effect is perceptible because water wets paper and water molecules can flow into the spaces between the fibres, weakening the adhesive force between them.

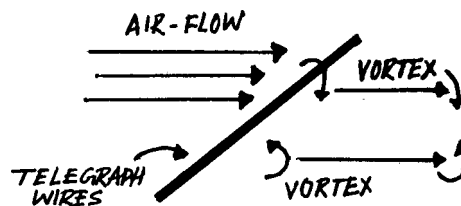
## The Invisible Pin



This vanishing of the pin is due to “total internal reflection” of light. According to the laws of optics, light rays from a point P (such as the tip of the pin) inside the water that are incident on the water-air surface at an angle greater than 48.5 degrees to the normal, do not refract and emerge from under the water into the air, but are totally reflected back into the water. The water surface behaves like a mirror to these rays. If the cork subtends an angle of spread equal to or larger than  $2 \times 48.5 = 97^\circ$  at the tip of the pin, no light ray from the pin can emerge into air and enter our eyes. Hence we are unable to see the pin.

## 6

## The Humming Wires



You might think that the vibrations of the telegraph wires in the wind produce the humming sound. Although these vibrations do produce some noise, they are not the main factors. When a fairly high speed wind hits a telegraph wire, the air flow becomes turbulent. Above a certain critical speed, two symmetrically placed stable vortices develop behind the telegraph wire. These vortices become unstable when the speed of the wind crosses an even higher threshold value. Then, if one of the vortices is somehow disturbed, it starts oscillating and ultimately breaks away. This is followed by the formation of other vortices in place of the earlier ones. This is technically known as the “hydrodynamic feedback” mechanism. As a result, a chain of alternating vortices flow away from the telegraph wire. These vortices are accompanied by rapid pressure variations in the surrounding air, which generate the characteristic humming sound. It was Lord Rayleigh who first made a systematic study of such phenomena.

## The Ben Hur Chariot Race

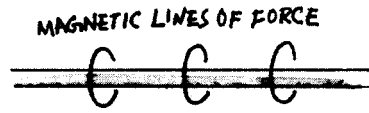
In film projection, 24-frames are projected per second. As a wheel picks up speed, there comes a stage when the wheel looks still. This is known as the “stroboscopic” condition. It is realized every time the wheel speed increases to a point where the configuration of the spokes remains unchanged over successive picture frames. However, just before this condition is realized, the wheel speed is such that the spokes just fail to arrive at their previous configuration. The wheel therefore appears to move backwards in spite of the increase in its speed. As the stroboscopic condition is reached, the wheel comes to rest, and then starts moving forward again as it speeds up further.

## The Invisible Man

In order for the “invisible man” to see, images of external objects must form on the retina of his eyes. This requires refraction of light at the outer surface of his eyes, which cannot occur. Moreover, some light energy must be absorbed by his retina in order for his brain to be triggered into interpreting the image. But then his eyes would become visible to others. An invisible man must necessarily also be a blind man! H.C. Wells’s “invisible man” could, however, see. This is scientifically impossible - a fallacy is a fallacy is a fallacy.



# Can Lightning Magnetise a Sword?



Lightning is discharge of electricity, and the resulting electric current passing through an iron sword would produce magnetic lines of force coiled around it. What are needed for magnetisation, however, are lines of force parallel to and along the length of the sword. However strong the current from a lightning might be, it cannot magnetise a sword unless it produces magnetic lines of force parallel to the sword. Moreover, even if the sword were somehow to acquire some magnetism, it should be completely destroyed by the enormous heat generated by the huge current arising from the lightning discharge.

## An Oscar-winning Problem

If you dip one end of a handkerchief in water, a large part of it gradually gets wet. This is because of capillary action. A handkerchief or any piece of cloth consists of a whole lot of capillary tubes with a fine bore. Water rises through these capillary tubes due to the action of surface tension (a blotting paper also works on the same principle) and eventually moistens a large part of the cloth. Exactly the same thing happens when a crumpled cloth is thrown onto water. As it starts soaking water, parts of it which are dry and above the water get wet and heavier; gravity then pulls these parts down. This combined effect of capillarity and gravity eventually straightens out the crumpled cloth. You can see this effect vividly by crumpling a piece of coloured tissue paper and dropping it into a bucket of water. You will be able to see the colour of the tissue darken as water soaks into it and the wet parts lower themselves on to the water surface.

## 36 Chowringhee Lane

The Director of the film was obviously overswayed by the dramatic compulsions of the scene and did not realise that wiping a frosty window pane from outside cannot help. This is because the water vapour inside the room which is warmer condenses on the colder window panes, and it is this moisture (frost) that needs to be wiped. The ambient temperature outside is obviously the same as that of the glass panes and so no condensation can occur on the outside. You must have noticed a similar effect during the monsoon on your car windows and windscreen which get misty.



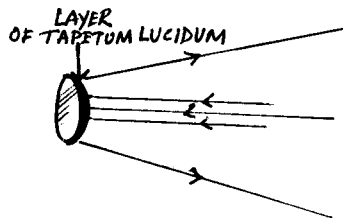
## The Murmuring Brook

It is the volume pulsation of trapped air bubbles in the stream that produces that murmur. The pulsating air bubbles behave like oscillating systems (bells) and generate sound waves in the audible range. You can create this murmur at home. Take two glasses partially filled with water. Pour water from one into the other and listen to the murmur. Notice that air bubbles form in the water.

## V Fly

When a bird flaps its wings downward, it forces updrafts of air which trail beyond its two wings. A bird following it is able to take advantage of these updrafts if it positions itself just behind the tip of one of its wings in order to avoid coming into each other's way. It is therefore most advantageous for migratory birds to fly in V formations. In this way they spend the least amount of energy. This is vital for very long distance flights which migratory birds have to undertake for survival. How did these birds learn this trick? We can only guess that evolution through natural selection must be the answer. Those species that did not develop the required "instinct" have not survived. Would you agree?

## Tyger ! Tyger! Burning Bright



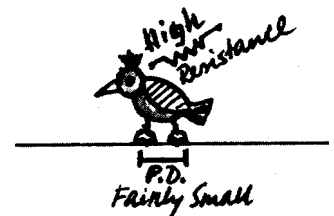
Unlike human eyes, a cat's or tiger's eyes contain a layer of tapetum lucidum which reflects light. There is a curved semi-transparent convex mirror of this substance in the cat's eye which reflects back part of the incident light into a diverging cone and makes it shine. If you are outside this cone, you won't see the eye at all. Presumably, it helps the tiger to spot its prey better at night by starlight.

## The Elusive Cricket

Our ears can determine the direction of a sound source in two ways: (a) by noticing the difference in the intensities of the sound heard by the two ears, or (b) by perceiving the difference in the phases of the sound waves reaching the two ears. Both form the basis of stereophonic hearing. Intensity differences are discernible by human ears only for short wavelength or high pitch sound. This is because long wavelength or low pitch sound can diffract or bend round the head and produce equal intensities at the two ears. For low pitch sound, our ears have to depend on their ability to detect the difference of phase at the two ears. At intermediate pitches (~ 4000 Hz) which roughly correspond to the sound produced by a cricket, the location of the source becomes tricky - our ears then find it difficult to differentiate between the intensities or phases at the two ears.

## Ignorance Is Bliss

The voltage drop across the two legs of a bird sitting on a high tension line is fairly small. Coupled with the fact that the electrical resistance of its body is high, this means that practically no current flows through its body. However, if an unlucky bird happens to touch the pole while sitting on the high tension line, it provides a short circuit from the line to the earth and a massive current flows through its body, electrocuting it.



## Pondskater



The surface of water is like a thin stretched membrane or “skin” which can support objects which are not too heavy, nor wetted by water and do not prick the skin. Insect legs are covered with an oily substance and are not wetted by water. Their legs simply depress this water “skin” created by surface tension. The skin tends to straighten out and support the insects.

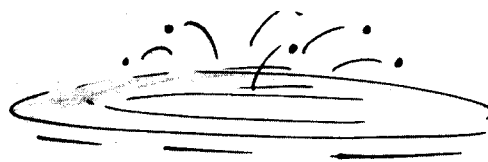
The feather of water birds like ducks are also covered with an oily substance exuded by their glands. This is why water does not wet their feathers.

## Darkness at Noon



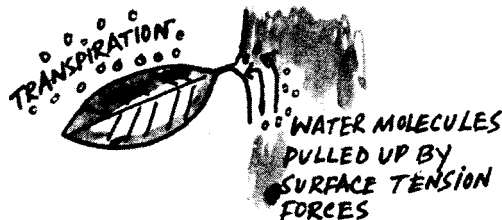
The real answer lies in the fact that water is closer to sand than air in its optical properties. Light is scattered by the sand grains but emerges fairly quickly after a few scattering events because the average scattering angle is large. When the inter-particle spaces are filled with water (even if it is pure) the average scattering angle is smaller and light suffers a larger number of scattering events and has to travel a longer distance within the sand before reemerging. It is this longer path and the consequent cumulative absorption by the scattering centres (sand grains) that make wet sand look darker. It has very little to do with absorption by water which is transparent to visible light. To convince yourself, use washed and clean sand as well as distilled water - the wet sand will still look darker.

## The Shape of Ripples



You might think that the waves will take some kind of an elliptic or oblong shape, somewhat wider along the direction of the stream. This is not true. The shape will remain circular in flowing water. The reason is this: the flow will translate the entire body of water downstream. Consequently, the circular waves will undergo a simple translation downstream without suffering any distortion.

## Sap in the Cap



Sap is lifted up to the leaves and then flows down with the products of photosynthesis. Water ascends from the roots through tubes of dead cells in the xylem. Products of photosynthesis descend from the leaves through living cells of the phloem. Experiments have demonstrated that the "motor" of sap ascent lies in the crown of the tree and is powered by sunlight. When the leaves are engaged in photosynthesis, they liberate copious quantities of water vapour to the air, a process called "transpiration". As water transpires a molecule at a time from the pores on the under-surface of the leaves, they are replaced by molecules pulled up from below by surface tension forces. The water column is continuous all the way from the rootlets to the capillaries in the leaves. It is therefore not the atmospheric pressure that is utilised but the cohesive forces within water and the adhesive forces between water and the cell walls. These cohesive and adhesive forces can give a continuous water column a tensile strength as high as 300 atmospheres. The formation of a single air bubble can however ruin this mechanism and make the sap drop to approximately 33 feet. That such delicate a mechanism can work reliably in the high, wind-tossed branches of a tree is because of the minute subdivision of the chambered structure of the wood. If a gas bubble forms in a column, the resulting break is confined to that column alone.

The mechanism of phloem transport, although mainly downward, is still not well understood. Osmotic pressure (the universal tendency of solutes to come to equal concentrations everywhere in a solution) could be responsible.

## Blue, O Blue Sea

Raman used the polarisation of light on reflection to test Rayleigh's contention. He used to carry a Nicol prism in his pocket. He took it out and looked at the reflected light from the sea through this polariser. He turned it round its axis to cut off the reflected light completely. He was surprised to find a beautiful blue light still emerging from the sea. This showed that the blue of the sea could not be entirely due to the reflection of the sky. This simple and ingenious experiment suggested that the blue of the sea must be essentially due to the scattering of light by water molecules. This struck Raman, and he started a whole series of experiments on the scattering of light by various liquids, culminating in his discovery of the Raman Effect (nothing to do with the blue of the sea as such) which won him the Nobel prize.

## Winter Veil

The reason lies in what is known as "temperature inversion". There are no strong air currents in the winter to disperse pollutants like smoke either in the vertical or horizontal directions. Also, the ground is not heated very much in the winter, and as the sun goes down, the ground radiates the heat into a clear sky and cools down fairly quickly. As a result, a layer of cold air gets trapped near the ground below warmer and lighter air above. This is the reverse of the condition that normally prevails, namely, the temperature of air drops with the height above the ground. The cold air near the ground cools all the smoke and other gases and traps them below the boundary layer between it and the warmer air above.

## **The Ghostly Moon**

The reason is that when the earth comes between the sun and the moon and casts its shadow on the latter, some sunlight is still refracted by the earth's atmosphere and falls on the moon, an effect usually neglected in textbook explanations of the lunar eclipse. This refracted sunlight is depleted of its bluer components because of the scattering of light by air molecules (called Rayleigh scattering). Air molecules are smaller than the typical wavelengths of light, and they scatter blue light much more than red light. This is why sodium vapour light is much more effective in lighting streets than neon light. Being yellowish, it is scattered much less than the bluer neon light and can penetrate deeper. This is why the light that falls on the moon during a total eclipse is faint and reddish.

## **Catch a Full Rainbow**

The centre of a rainbow is always in line with our eyes with the sun behind us, so that standing on the earth, we are only able to see semi-circular rainbows. The lower halves of the bows (with their axes parallel to the earth) are cut off by the earth. A complete rainbow can only be seen when it is formed parallel to the earth's surface, as seen by the passenger in an aeroplane flying above the water droplets with the sun high up above it - a rare combination.

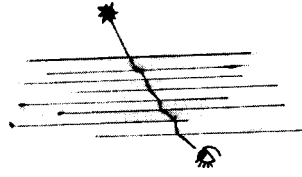
## **The Moon and the River**

The crux of the matter lies in the fact that the moon is a very, very distant object and the height of an aeroplane above the ground is negligible compared with this distance. Now, for an image in a plane mirror, the image distance is the same as the object distance. The image of the moon in the river is also therefore very, very distant. Since the height of the plane is negligible compared to this distance, the moon's image will appear to have the same size from the ground and the plane. However, the width of the river will appear to shrink as we go up. Hence there will come a point above which the river will appear narrower than the reflected moon.

## **Olber's Paradox**

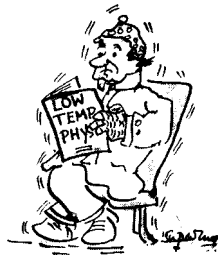
The darkness of the night sky is essentially explained by the universe being still young and expanding. In an expanding universe, the distant sources of light (the galaxies) are all receding from us. This leads to a diminution of light from a galaxy in two ways. First, there is a difference in the time scales which operate on the earth and on distant galaxies. This difference alters the rate at which light is received on earth from a distant galaxy. The amount of light which is emitted by a galaxy in a given period is received on earth over a longer period compared to the galaxy clock. There is also an associated effect known as the "cosmological red-shift" (a consequence of the general theory of relativity) which shifts an appreciable portion of the visible light into the infra-red region which is not visible. These effects combine to ensure that the distant sources of light in the universe do not make the night sky bright. The finiteness of the universe in extent or in age reduces the remaining brightness of the sky to the observed level.

## Twinkle, Twinkle, Little Star

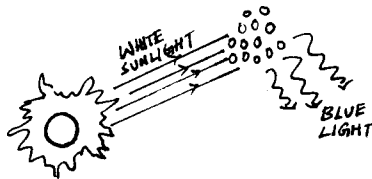


The twinkling of stars is caused by the earth's atmosphere. Stars are so far away that they act as point sources of light. Due to constant movements of air in the atmosphere, the rays of light from a star undergo random deviations as they pass through the turbulent air currents. As a consequence, the position of a star appears to us to fluctuate as well as the intensity of light from it, giving rise to the twinkling effect. If you were on the moon, for example, where there is no atmosphere, you would not see stars twinkle.

On the other hand, planets are comparatively nearer to the earth and they look like small discs of light rather than point sources. Although the turbulence in the earth's atmosphere produces fluctuations of each point in the disc, these fluctuations cancel each other out over the disc and the total effect is one of steady light.



## The Blue Dome of Air



Light from the sun spreads out through space like ripples on the surface of a pond. These ripples or waves have very small wavelengths (the distances between successive crests or troughs) of the order of  $0.00006$  cm. When they fall on air molecules in the earth's atmosphere which are much smaller in size, these waves scatter off these molecules in a particular fashion. Lord Rayleigh was the first to show theoretically that the intensity of the scattered light should increase sharply as its wavelength decreases. In the visible spectrum of sunlight violet has the shortest wavelength. It, therefore, follows that violet light should be more scattered into our eyes than blue, green or red light. But then why does the sky look blue rather than violet? That is because of two other important factors. First, there is more blue light in the sun's rays than violet. Secondly, our eyes are much less sensitive to violet than to blue light. Through evolution the human eye is adapted to be most sensitive to the colour most abundant in the sun's rays, which happens to be yellow. These two factors make the resultant visual sensation dominantly blue.

## **The Blue Zenith**

This enhanced blueness of the zenith is owing to the presence of ozone in the upper layers of the atmosphere. Absorption of light by ozone is highest at the red end of the spectrum and is least at the blue end. When the sun is just below the horizon, the path length of sunlight through the ozone layer is the greatest at the zenith, and consequently it is most depleted of its reddish components.

## **Once in a Blue Moon**

What Robert Wilson concluded from his observations was that the blue sun and moon were caused by clouds of small particles from forest fires in Alberta (Canada), which had been carried by winds across the Atlantic to Edinburgh. These particles were predominantly oil droplets formed from the combustion products of the fires. These oil drops had sizes comparable with the average wavelength of light. Now, we know that if the scattering particles are much smaller than this, they preferentially scatter blue light (Rayleigh scattering). If they are much bigger, they scatter all colours more or less equally. When they are of a comparable size, they scatter red light more than blue. It so happened that the oil drops carried from the Canadian forest fires to Edinburgh were just the right size to scatter red light more than blue. Consequently the sun and moonlight that got through looked blue. It was indeed a very rare combination of factors. Such a combination occurs only once in a blue moon!

## **Halo Moon**

The white band around the moon is called a halo. This halo around the moon is caused by refraction and dispersion of light. You might have noticed thin white clouds in the sky, so thin that we can see the moon through them. These clouds are made up of tiny hexagonal ice crystals. The rays of the moon coming through the crystals are refracted as in a prism. The refraction is also accompanied by dispersion, that is, splitting into colours. The halo looks circular because the crystals are uniformly distributed around the centre of the halo. It actually looks pinkish (not white) because of the central pink colour, which can be seen distinctly, while the outer blue colour merges into the background of the sky.

**end**