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Everyday observations in relation with Natural Sciences

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Summary[1]

To a large extent, Natural Sciences are based to data collection from (systematic) observations. The development of observation skills from where data are collected and, based on these data, models are formed and conclusions inferred (must) constitute a primary objective of the Teaching of Natural Sciences. In this work, some cases are presented in which speculations are made using Science knowledge and applying models on situations, which may be encountered in everyday life. In every case a summary description of the situation (phenomenon and/or model assumed) is presented. On this base one or two speculations are further exploited and some more are suggested as examples or questions.

Important information to one is passing unnoticed for another. Or, as Kavafis[1] says

Θεοί μεν γαρ μελλόντων, άνθρωποι δε γιγνομένων, σοφοί δε προσιόντων <u>αισθάνονται.</u>
Φιλόστρατος, Τα ες τον Τυανέα Απολλώνιον, VIII, 7

ΣΟΦΟΙ ΔΕ ΠΡΟΣΙΟΝΤΩΝ

Οι άνθρωποι γνωρίζουν τα γινόμενα.
Τα μέλλοντα γνωρίζουν οι θεοί, πλήρεις και μόνοι κάτοχοι πάντων των φώτων.
Εκ των μελλόντων οι σοφοί τα προσερχόμενα αντιλαμβάνονται.
Η ακοή αυτών εν ώραις σοβαρών σπουδών ταράττεται.
Η μυστική βοή τούς έρχεται των πλησιαζόντων γεγονότων.
Και την προσέχουν ευλαβείς.
Ενώ εις την οδόν έξω, ουδέν ακούουν οι λαοί.

Κ. Π. Καβάφη, ΠΟΙΗΜΑΤΑ (1896-1918),
Φιλολογική επιμέλεια Γ. Π. Σαββίδη, ΙΚΑΡΟΣ, Αθήνα 1966

1. Introduction. You are in deep thoughts when a barking calls off your attention. What can you possibly infer?

Here are some replies[2]:

- It is a dog
- It is a stout danish dog
- It is a small white peking dog
- Where on earth this stray dog came?
- Attention to this shepherd dog
- It is our dog's drive time

- The TV is loud
- Maria tests recorded sounds
- John practices again imitations
- Our cat advances in foreign languages

Replies in the first column refer to situations where a dog is barking. In the second column, the barking is assumed to come from other sources, the last one referring to a joke[3]. Forgetting the joke, all the replies are possible although none of them may be fully supported from the 'data' given. When a justification for every reply was on demand, the students on whom the question was posed, completed the situation described in the question, mostly according to their previous experiences. On the basis of their experiences also, they all rejected the joke answer as pure fiction. When asked to speculate on which of the replies seems to be the most plausible, they started reasoning like ‘If the situation is so and so then we may exclude this’ or ‘we may consider further that’ etc. From this point onwards, the planning of specific inquiries to test the validity of the replies given at first, was a relatively easy task.

Open type questions are considered as appropriate for the development of creative thinking. The description before was made only to demonstrate the appropriateness of the open type questions in forming models, a basic skill in Science and especially its core, the Physics. In Physics, knowledge is accumulated by a repetition of the following steps, termed as ‘scientific methodology’:

1-A. Making observations from which ‘relevant data’ are collected.

1-B. Examination of the data trying to discover patterns, e.g. relations between them or between them and other data.

1-C. Making assumptions (hypotheses) about the patterns discovered.

1-D. Testing these assumptions. Planning and conducting specific inquiries (‘scientific inquiry’), usually in the form of experiments, do the testing. The outcomes of these inquiries may reject some of the assumptions made. The goal is to reject all but one of the assumptions made.

1-E. On the basis of the non-rejected assumptions models for the world (or rather that part of the world, which was examined) are formed. From these models complete theories may evolve in an inductive process.

1-F. Applying these models predictions may be made by deductive reasoning on what will be observed in other situations. Then, if what is really observed is in disagreement with the predictions made, the model has to be redefined.

1-G. In all the steps above, a way of communicating the findings and thoughts in a clear, precise and unambiguous way is essential.

Reading these steps one may infer that the observations for the collection of data (see step 1-A.) precede the formation of hypotheses and theories, i.e. scientific methodology is an inductive from the data process. Many philosophers dispute this view on the basis that in order to collect ‘relevant data’ from the observations, one must have formed already a criterion to distinguish relevant from non-relevant data i.e. one must already have a model, even in a primitive form from which deductions are made and tested. This dispute between ‘inductionists’ and ‘deductionists’ has been proven over time very fruitful for the advance of human reasoning. More on this point may be found in the literature (see for example **4**, **5**, **6**, **7**, **8**, **9**). I note however that the steps described above are repeated continuously so that observations and theories are interwoven and advance in step, one following the other. That is why, although modern theories are ‘more correct’[10] than older ones, we expect them to be replaced by even ‘more correct’ theories on the basis of new observations[11].

Steps 1-C and 1-E above are very advantageous for the development of creative thinking. This however depends heavily on the efforts made to try and form new hypotheses, models or theories, which are supported by the data but are also alternate to the (currently) acceptable ones[12]. From this viewpoint the teaching must be done in a form encouraging students to try and invent as many models as they can to explain the data observed. The commonly encountered practice in Science teaching where from an observation or an experiment only one conclusion (the ‘correct theory’) is inferred does not improve creative thinking and has also other drawbacks.

A simple form of prediction is to calculate the value of a quantity by interpolation or extrapolation of other values taken or by using a relation (‘physical law’ expressed by a ‘physical equation’) with the values of other quantities. Another form of prediction is made by posing questions of the type ‘what will happen if …’ and trying to answer these using the model or theory. A prediction as referred to in step 1-F (and, indirectly in steps 1-D and 1-E) may also be expressed formally as the conclusion of a valid according to Logic argument. In this argument one of the premises expresses the data from the observations and the other expresses the model or the theory. If the conclusion is tested (usually with an experiment or with another kind of observation) and agrees with the data obtained, no further action is necessary. However if the conclusion and the observations do not agree, an examination of the whole procedure is necessary to see the cause of the disagreement. This disagreement may be due to:

1-a. Premise of observation not true (e.g. incorrect or wrong measurements),

1-b. What actually observed is not what it is thought to be observed,

1-c. Error in the premise of theory (wrong application of the theory),

1-d. Error in logic, i.e. formation of an invalid argument,

1-e. The premises are true, the argument is valid still the conclusion is not true (i.e. it is in disagreement with the observations).

Errors of case 1-a, 1-c and 1-d may be spotted and corrected with a relative easy. In case 1-e it is clear that the theory (or the model) does not describe accurately enough the observations made and there is need for modification[13]. The situation however is not always as clear as it may seem, especially in distinguishing between cases 1-b and 1-e. As an example take the neutrino particle (ν). In the late ‘30s experimental evidence was accumulated from radioactive fission in which the total energy and momentum before the fission did not match the measured total energy and momentum of the fragments. It was thought that there was a case 1-e present and the theory (axiom) of Conservation of energy and momentum had to be abandoned but Pauli[14] postulated the existence of a new particle, without rest mass and not detectable in the foresaid experiments. That particle would account for the difference in energy and momentum observed, that is he speculated on case 1-b instead of accepting case 1-e. The discovery of planets Neptune and Pluto may also be considered as similar paradigms[15] between case 1-e (i.e. rejecting the gravitation theory of Newton) and case 1-b (i.e. accepting a situation different from the assumed).

It is clear that observation and proper communication skills and, also, model understanding is of fundamental importance in Science. Some aspects of them are discussed briefly in this work.

2. Observations. According to the ancient Greeks ‘νους ορά και νους ακούει[16]’ According to the Concise Oxford Dictionary, within the framework of a scientific investigation, ‘observation’ means the accurate watching and noting of a phenomenon etc. or a measurement or other result so obtained. Effective observations require special skills (compare with the taxonomy of the cognitive skills used in the theories of learning), such as the following:

2-a. Recognizing parts or specific components in a complex situation and spotting out their characteristics, i.e. finding ‘facts’. Noticing similarities and differences is a closely related skill.

2-b. Classification of the facts according to some criterion. This criterion depends on the specific investigation planned.

2-c. In Physics, the observations usually involve estimations on the values of different quantities (e.g. distance, weight, temperature, force, energy, etc). These estimations may be in the form of simple comparisons with other similar ones (e.g. this object is heavier/lighter than that) or in the form of measurements (i.e. the weight of this object is 1kg). Perception of the magnitudes of the quantities involved in a physical observation even in a comparative form is fundamental.

2-d. Communication of the findings in an appropriate form.

2-e. Distinguishing between the ‘facts’ from the observation and their corresponding interpretation within the context of a model or theory. Although models and theories are useful in the finding and in the classification of facts, the distinction must always be remembered.

In point 2-a above, in order to recognize and distinguish parts of a whole, analytic and synthetic cognitive skills are necessary. Once these parts have been isolated, their description with similarities and differences refer to physical quantities such as the size, the state and type of motion, the vegetation, the temperature, the color, the mass and weight, the pressure, the state (e.g. solid, liquid or gaseous), etc. This is done using our senses but, sometimes, special instruments or techniques are necessary.

Point 2-b requires the existence of a criterion. This criterion (‘classification parameter’) may refer to a quality (e.g. color, shape, size, etc), to structure (e.g. biped or quadruped, arthropod, …, bush, turf, tree, …), to behaviour (e.g. bird of passage – migrant, deciduous or evergreen, etc) that is observable. From this classification groups and broader sets may be formed. The formation of ‘working definitions’ is also a very useful tool. This working definition may be given either descriptively, with examples, by a ‘definition rule’, by enumeration or by other ways in analogy with the ways of defining a set in Mathematics. Although working definitions may be not complete they must be non erroneous and represent clearly the observations. Using the correct terminology is a basic element on which an effective Science teacher must insist[17].

Estimations for the values of some quantities may be made without instruments by using senses if the values are within an appropriate for the senses range. Such quantities include distance (length, width, height), surface and volume, pressure, acceleration, speed, brightness, etc. Measurement refers usually to obtaining the values of a physical quantity using measuring instruments (see point 2-c above). Related to the measuring instruments are the notions of accuracy, of sensitivity[18] and of range[19]. With most measuring instruments the value of the quantity to be measured is indirectly obtained by measuring the value of another quantity. The two quantities are related by a model or theory. For example, in the balance scale, the quantities compared are the torque of the weight to be measured and the torque of the weights. According to our model the torque is equal to the weight times a distance determined by the construction of the balance. Another example is the traditional thermometer in which the temperature is obtained from the elongation of the thermometric liquid inside the tube and the (supplied by theory) relation between this elongation and the temperature. The measurement error denotes the difference between the ‘true’ (but unknown) value of the quantity to be measured and the value obtained from the measurement. It may be due to limitations of the instrument (for example because of an inaccurate model or an inaccurate calibration[20]) and may be distinguished in systematic and random. The estimation of the (possible) measurement error is often very tedious involving complex processes.

Doing observation to get data we must be aware about the independent variables, the dependable variables and other (‘constant’) variables involved. Independent variables in an experiment are controlled and refer to physical quantities whose values may be adjusted at will (within a range). Dependable variables refer to physical quantities whose values vary in reaction to a change in the values of the independent variables. For the values of other quantities that may also be involved but are not objects of study in a specific observation, care is taken (or it is assumed) to be kept constant (hence the term ‘constant’ variables’). The outcome of a measurement depends strongly on a clear understanding of the important factors that may influence significantly the data obtained and the relations between them. A kind of understanding is also useful when the purpose of an observation is to discover these relations (see also the comment made previously about the inductionists and the deductionists).

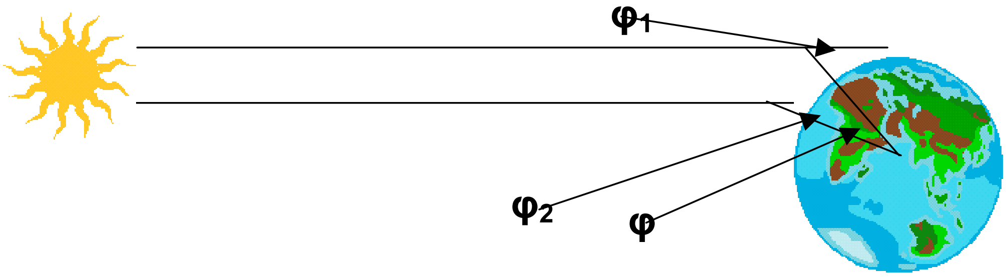
In point 2-d above, the communication of the findings may be done verbally (oral or written reports) with the use of pictures, diagrams, tables, graphs, etc. Understanding these techniques is essential.

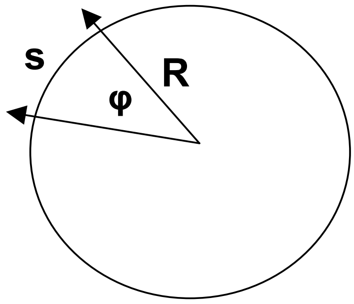
The distinction between observation findings and their interpretation according to a theory (see point 2-e above) seems to be a subtle one. We observe that “a stone falls down” and not that “the earth’s gravitation pulls the stone which then falls down”. The later is our theory to interpret this and other observations. Similarly, in a simple electric circuit with a battery, a switch and a light bulb, when the switch is closed we do not observe that 'electric current passes and bulb lights”[21].

3.-Models. Models are a mental representation of our understanding of the physical world or, at least the part of the world studied. A model includes concepts originating from events in the (physical) world (‘physical phenomena’)[22] and relations between these. For example, one such relation is in the form of cause and effect. Quite often we use a model, which was developed to describe one situation as a way to describe a completely different situation. In these cases we use the relations of the model to connect different sets of physical phenomena. An example is the use of the solar system model to describe the atoms. In this ‘analogy’ the sun is replaced by the atomic nucleus, the planets by the electrons of the atom and the gravitational force by the Coulomb force between the nucleus and the electrons. In this way, models play an important role in extending our understanding of physical phenomena beyond the range of our senses. However, using this kind of analogy must be made with caution as to the range the analogy may extent. In all the cases understanding the model is essential. An expression of understanding a model is the ability to apply it to various real situations and make predictions from it. For example (see Figure 1), Eratosthenes[23] using the model of a spherical earth and simple geometry calculated the Earth's circumference with an astounding for his time precision. With similar devices and reasoning and taking into account the ‘spinning’ of the earth and its rotation around the Sun, the longitude and the latitude of a place may be measured[24]. The cause for the asymmetric with respect to the local noon increase (or decrease) of daylight time may similarly be investigated (obtain relevant data from a desktop calendar).

4.-Some Examples. In the rest of this work we present some cases where using Science knowledge and applying models we speculate on situations, which may be encountered in everyday life. In every case a summary description of the situation (phenomenon and/or model assumed) is presented. On this base one or two speculations are further exploited and some more are suggested. These are given as examples and only main points are discussed. The interested reader may speculate further.

Figure 1.- Sperical Earth model





The downward extension of a vertical rod passes through the sphere's centre. A plane perpendicular to a vertical rod is called horizontal plane. A vertical rod is along the path of a free falling (heavy) object. Two vertical rods at different places of the sphere's surface make an angle **φ = s/R** (see diagram). Because of the large distance between the Sun and the Earth we may assumme that Sun's light rays reaching Earth are parallel. Simple geometry then shows that **$\varphi = \varphi_1 - \varphi_2$** (see picture).

Eratosthenes used Alexandria and Aswan as the two places. Their distance was known accurately enough from the official courriers travelling frequently between these two administrative centres of ancient Egypt. The value he obtained corresponds to an Earth's radius of 6.2 10^3 km as compared to the currently accepted value of 6.3 10^3 km.

The angles **φ_1** and **φ_2** must be measured at the same time. As modern clocks or other 'instant' communication methods were not available that time to solve this 'synchronization' problem, we may assumme that Eratosthenes:

Either exploited the fact that Aswan was southwards of Alexandria, that is the two places are on about the same meridian and used the corresponding angles when the Sun was at its highst point (local noon),

Or he (his assistants) measured the two angles at some time during an eclipse.

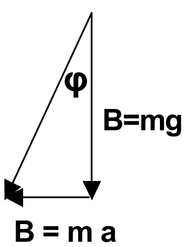
Figure 4-1. Airplane landing speed.

$g \sim 10$ m/s^2, $\varphi \sim 25^o$

➔ $a \sim 5$ m/s^2, $t \sim 20$ s

speed ~ 100 m/s = 360 km / h

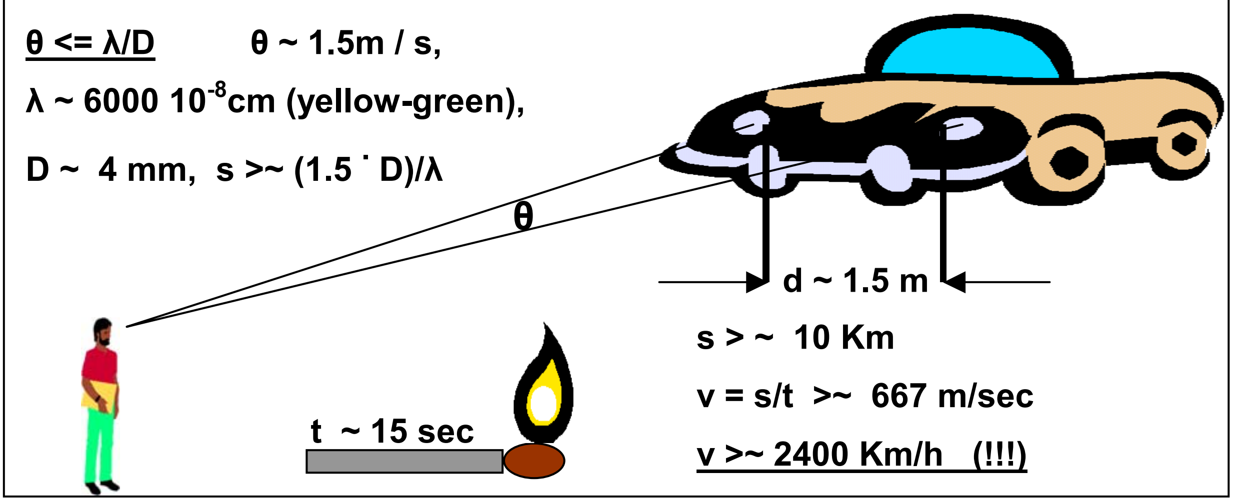
$s = 0.5\, v\, t \sim$ 2 km



4-1.- Airplane landing speed. During landing as the airplane touches ground starts decelerating. We may assume that this deceleration is constant and at the end the airplane stops completely. On this basis, a passenger may estimate the speed with which the plane touches the ground from the known relation **speed = acceleration** multiplied by the **time** (plus and minus signs are not important in the context here). During this ‘landing time’, the airplane covers a distance, **s**, (see Figure 4-1). Measurement of the time poses no problem, it may be estimated even by a constant rate counting. The acceleration may be estimated by noticing that the passenger feels his/her weight not directly downwards but tilted in a forward direction. An estimation of this ‘tilt’ angle permits the evaluation of the acceleration. This angle may be measured more precisely with a simple pendulum and a protractor. Using such a simple device and a stopwatch, the values **$\varphi = 20^o$, t = 25 ➔ speed ~ 328 km/h, s ~ 2.3 km** were obtained and may be compared with the corresponding values given in Figure 4-1, which were obtained mentally. The same procedure may be used to obtain the takeoff speed. You may think if any difference is expected, verify your prediction by observation and speculate on the reasons of any difference observed either between the values predicted and observed or between the takeoff and the landing speeds.

4-2. A TV Commercial. A TV commercial had the following theme. The scenery shows a saloon in the middle of nowhere at twilight. A person of the cowboy type strikes a match to light a cigar when, far in the horizon, one light catches his attention. He freezes staring it and sometime later a car (vroom, vroom, vroooo…m) passes. At this time the match burns the finger of the ‘freezing observer’. Is it possible to make any estimation on the car’s speed? Well, the speed, **v**, may be estimated if the time, **t**, and the distance, **s**, could be estimated. Let us see what data may be collected from the preceding description. The time elapsed is the burnout time of a match and we can measure it. According to the description, the distance covered by the car during this time is at least the distance between the

Figure 4-2.A TV Commercial



observer and a point so far away that the two headlamps of the car are confused as one. From optics we know that two objects at a distance **d** between them may be confused as one if they are so far away that their viewing angle, **θ**, is smaller than the ‘resolving power’ of the (optical) instrument used to view them, i.e. **θ <= λ/D** (see Figure 4-2) where **λ** is the wavelength of the light used and **D** is the diameter of the ‘aperture’ of the instrument. But the same angle **θ** is also given by the relation **θ = d/s** where **s** is the distance between the aperture of the instrument and the two objects. In this case the instrument used is the eye of the observer and **D** is the diameter of the eye’s pupil. As wavelength we may use a value in the yellow – green area where the highest sensitivity of the eye is. Using the approximate values given in Figure 4-2 the speed obtained does not represent a car.

4-3. Big brother watches you. Artificial satellites are orbiting at an altitude of 2 to 5 thousand km and many of them are used for surveillance of the earth surface. For this surveillance they use either short wavelength (high frequency) electromagnetic radiation with typical wavelength in the cm (e.g. the type used for satellite TV broadcasting) or in the mm range (e.g. the type used in cellular telephones) or infrared light (wavelength in the range of 10^{-6}m). However as energy resources in the orbiting satellites are limited, the emission power is low and as the atmospheric meteors at these distances largely attenuate infrared light and consequently infrared surveillance of this kind is not very feasible. Recently it was published in the newspapers that the surveillance by artificial satellites might reveal even the trademark on a pack of cigarettes. We may speculate on this. Satellites are not very extended so we may expect an upper limit for the aperture of the cameras used in the order of 20 cm at most. Using the 'resolving power' limitation as in the previous example, the shortest distance, **d**, between two objects in the earth's surface, that a satellite may 'see' is $\mathbf{d = (h \times \lambda) / D}$ where **h** is the satellite's altitude **λ** the wavelength used and **D** the camera's aperture. For an altitude as low as 2000 km, the shortest distance, **d**, a satellite may 'see' on the earths surface using short wavelength electromagnetic radiation is in the order of 100km or of 1km (for the cm or the mm range) and 10 m using infrared light (provided enough power may be obtained). With one satellite the newspaper statement does not seem feasible. However, if the signals from two or more cameras located on different places may be synchronized then in effect a camera with an aperture of a much larger size is made (see more in any book on optics)[25]. For example, if the two cameras are at the opposite ends of a satellite with extending wings (D ~ 20m) the corresponding values become 1km, 100m and 10cm. For cameras located in two different satellites (D ~ 2000km), the corresponding values are in the range of the wavelength used (however the picture is blurred because of noise and problems of synchronization). In another surveillance method, the satellite detects the radiation (thermal or electromagnetic) emitted from objects in the earth surface. This radiation is then screened, analyzed and retransmitted to special stations. Satellite surveillance is useful for communications, weather broadcasting etc.

4-4.- Circulatory System[26]. For an explanation of the workings of the circulatory system a mechanical analogy with a pump[27] and an appropriate circuit of pipes may be constructed and observed[28]. The extent of the validity of the analogy may be tested by observing the differences (if any) of the blood pressure in standing up and in lying positions measured on different parts of the body (neck, hands, legs) and interpreting the findings as hydrostatic pressure differences. With this analogy we may speculate e.g. why it is lethal to have air bubbles in the veins or what the consequences would be if an insoluble object finds its way within an artery or within a vein (thrombosis). Aspects on the hygiene of the circulatory system may also be demonstrated by this analogy. For example, scaling is often observed in water pipes. May this happen also to the blood vessels of the body? What then may be the consequences? What factors may enhance or prevent such a condition (relation with food and inhalation)? If the arteries lose their elasticity what would be the consequences (such a condition is known as atherosclerosis and is associated with high cholesterol levels). As another example let us speculate on the alcohol test used to prevent driving when drunk. Under the assumption that through the digestive system alcohol is transferred to the blood very rapidly[29], the alcoholic content of two wine glasses (~250ml) filled with a very light (12% volume) wine is

30ml and, for the typical blood quantity of 6lt of a grown up adult person, this raises the alcoholic content of the blood to 0.5%. This is the upper limit in most states for a legally safe driving[30].

4-5.- Kinetic Theory. Many physical properties of matter, especially these related to heat and temperature, may be explained in terms of the behavior (movement, potential energy, etc) of its particle components (e.g. atoms, molecules, radicals, etc), which move in a chaotic way ('thermal motion'). This same model has been applied to other situations also such as the clusters of stars or galaxies, the 'free' electrons in a metal, the nucleons (neutrons and protons) in (heavy) atomic nuclei, etc. In the kinetic theory model, the centigrade (or Celsius[31]) temperature, **Θ**, of a physical body is related to the average value of the kinetic energy, **E**, of its particles by **Θ + 273.15 = T = E / k,** where **T** is called the absolute (or Kelvin[32]) temperature and k is called Boltzman's constant[33]. Speculations on this model may explain observations on the properties of physical bodies as their state (solid, liquids, gas) and changes of it (melting, evaporation, etc), the expansion of (most) substances when their temperature is increased, etc. Despite their motion, the constituent particles of the body remain closely together because of the mutually attractive forces between them[34]. However some of them may acquire enough kinetic energy to overcome the attractive forces from the rest and escape. The particles left will have a lower average kinetic energy, that is a lower temperature. This is the known phenomenon of evaporation and provides an explanation on the chilling we feel after a warm bath while we are still wet or the similar feeling when a volatile substance (such a the surgical spirit) is spread on our skin. In the past, where refrigerators were scarce or did not exist, the 'sweating' pottery from Aegina, an island south of Athens, used the same mechanism to make fresh water. Using the same mechanism in the hot summer Mediterranean days, a warm to hot water melon may be transformed into a refreshing (and hopefully delicious) meal if cut into (thin) slices and exposed further to direct sunlight for one or two minutes. A good understanding of the consequences of this simple model may explain, in a qualitative way at least, why stirring a hot liquid lowers faster its temperature, why dissolving a solid in a liquid (usually) lowers its temperature, even if the two substances have the same initial temperature[35], why we 'see' our spoken words in dry cold weather, why rubbing two objects (e.g. your hands) their temperature increases, (faster if their relative motion is faster)[36] or why frost is mostly observed during clear sky Spring nights. Observations, which at first sight may seem inconsistent, may also be explained. For example, during humid hot summer days, opening the side door of a freezer a kind of 'white smoke' (condensed water vapor from the atmosphere) is observed to fall down. However if you open the top cover of a freezer (e.g. of the kind ice creams are kept in the kiosks) you see the same 'smoke' to go upwards. Further similar examples include blowing which may blank out a candle but explode a fire, or may warm our hands but cool down our soup.

4-6. Driving. The default speed limit in urban areas is 50 km/h. However in most Greek villages this limit is less, 40 or even 30 km/h. Let us speculate about the justification for these limits. It is evident that 'the lower the speed the safer the driving' cannot be accepted[37]. We may assume that the speed limit, if reasonable, is the highest speed, which permits a safe full stoppage at an emergency. The main parameter then is the distance the car will travel from the time the emergency is realized by the driver until the full stoppage of the car. This may be split further to the distance the car will travel in the time between the apprehension of the emergency from the driver until the reflexes of the driver move his leg to the brakes and the distance the car will travel during the braking time. The reflection time of an alert driver may be assumed 0.5 seconds in which a car with a speed of 36km/h will cover 5 meters. The distance traveled during braking time depends on the maximum safe deceleration, **γ**, which depends on the coefficient of friction. For a deceleration as large as 5 m/s^2 (i.e. half the gravity acceleration, g)[38], the same 36 km/h car will cover 10 m. In total the distance traveled will be 15 m. The distance in effect will be much higher, even for this relatively low speed, if the tyres are not in a proper condition, if the road is wet, if the driver is not alert (e.g. a sleepy or intoxicated driver), etc. This distance may be compared with the distance between two road crossings or the time a pedestrian may need to cross a road in many of the Greek villages with the narrow streets and small blocks. Further speculations may show the importance of the functioning of the back red stoplights, the safe distance to be left from the car ahead, especially on motorways, etc. Using knowledge from kinematics (i.e. the centripetal – centrifugal force, the gyroscopic effect, etc) speculations may be made about the easy of balance of moving cyclist in comparison with a standing one, the different tyre shapes for cars and motorcycles, the inward round slope of the highways, etc.

4-7. Etc. Using simple knowledge, especially from mechanics, which is always taught in schools, speculations may be made on the following:

- The inward thickness of the Earth's crust in mountainous areas and in the sea (compare with the draught of a large ship and a small boat)?
- How strong are the tendons in the legs or in the arms (use lever mechanics)?
- Why are there usually rivers in the gorges ?
- Why the string for drying the laundry has to be loose?
- Why commercial ships do not usually sail on their full speed (speculate on fuel consumption)?
- Why long car queues are formed even in slight road narrowing?
- Etc.

4-7. Epilogue. Applying Physics knowledge in common life situations may be fun. At least I have always enjoyed the preparation of these lectures.

Notes and References

1. This work is a summary of lectures given to post-graduate students in University Departments (mainly Departments of Education) and presumes only a basic knowledge of Physics, i.e. at the level of the upper secondary school. In this work, biographical data have been collected from various sources, mostly from the Webster's Concise Encyclopaedia CD-Rom version 1.23 of 1994 and the Encyclopaedia Britannica CD2000 CD-Rom.

2. Although in many cases a synthesis has been effected, the paradigms in this work have been collected from actual teaching. In this specific question there was an extensive overlapping of similar replies from children (in elementary school), teachers (in training courses) and University students. However the follow-up was different with the elementary school children being more eager (and usually more inventive) in their replies than the grown –up, many of who showed a visible hesitation.

3. A mouse chased by a cat takes refugee in its nest. Sometime later it hears a barking, assumes that because of the dog the cat drew away, gets out only to be found in the cat's mouth. To his wonders the cat replied 'a foreign language is necessary for today's living'.

4. A. F. Chalmers, 'What is this thing called Science? An assessment of the nature and status of science and its methods', University of Queens land Press, St. Lucia; it has been also translated in Greek by the University Editions Of Crete'

5. Stephen F. Barker, 'The Elements of Logic', McGraw-Hill book Company 1989

6. Steven M. Cahn, 'A new Introduction to Philosophy', Harper & Row, publ. 1971

7. 'Teaching Science', Routledge, 1994, edited by Ralph Levinson at The Open University.

8. Albert Einstein – Leopold Infeld, 'The evolution of Physics', translated into Greek by E. Mpitsakis under the title ' The evolution of ideas in Physics', Dodoni editions,

9. Max Born, 'Experiment and Theory in Physics', Cambridge University Press; it has been also translated in Greek by G. Georgakopoulos, TROXALIA editions.

10. That is they describe better the data we collect from the observations.

11. Or a new way of thinking, a path left to philosophers.

12. The formation of more than one hypotheses or models with differing predictions is also necessary for steps 1-D and 1-F.

13. Always staying within the current formality of Logic. Another type of Logic (i.e. another way of reasoning) means another type of Humans.

14. Pauli Wolfgang 1900–1958. Austrian physicist awarded in 1945 the Nobel Prize for his work on atomic structure.

15. Neptune the eighth planet was located 1846 by the German astronomers J G Galle and Heinrich d'Arrest (1822-1875) after the suggestions to them based on calculations the French mathematician Urbain Leverrier. The English astronomer John Couch Adams and the French mathematician Urbain Leverrier had predicted its existence and calculate its positions from disturbances in the movement of Uranus. Pluto is the smallest and the outermost known, until now, planet of the Solar System. Percival Lowell (1855-1916) predicted by calculation the existence of Pluto and Clyde Tombaugh located the planet much later in 1930. Tombaugh worked in the Lowell Observatory at Flagstaff, Arizona founded by Lowell Percival.

16. In a liberal translation 'we see and hear with our mind'.

17. Words, which within the context of a science represent a technical term quite often have also a similar or quite different meaning in everyday life in which other, more colloquial, words are also used (see for example the words alcohol, work, energy, etc). It is incorrect to replace within the context of science the technical terms by more familiar words because 'a simple, direct and easily understandable language must be used when dealing with very young's', as it is often observed in some textbooks.

18. Sensitivity refers to the amount of the measured quantity necessary to produce a change in the measurement. The smaller the quantity the higher the sensitivity. Accuracy means that the value obtained is the correct value for the quantity measured within the sensitivity of the instrument and the measurement error. According to John, a high school student, accuracy of a scale means that an object of 1 kg is measured as 1 kg and sensitivity means that the measurement will change if we add or subtract a tiny amount.

19. For example, the carpenter's rule is appropriate to measure lengths with values in the range he uses to but it is not appropriate to measure very short (e.g. atomic distances or the thickness of a sheet of paper) of very long (e.g. the distance between two cities or between two stars) distances. However in some cases a 'smart use' may 'extend' the range of an instrument. For example with a carpenter's rule we may measure the thickness of a book and then calculate the thickness of a single sheet (assuming that all sheets have the same thickness and they are tightly packed).

20. For example if the subdivisions of a meter scale are placed incorrectly, the measurements obtained will be systematically in error.

21. These are actual replies from teachers in a training course and from University students. Such a confusion is encountered less frequently with school children, may be because they do not have been taught the "theory"

22. According to Einstein the stimuli to the senses caused by physical phenomena are transformed to concepts. These concepts may be different to different persons. However their common origin (the specific physical phenomenon) permits a one to one correspondence between these different concepts different persons may have. This is a characteristic only for concepts, which originate from physical phenomena. Einstein calls these concepts 'truth' and their study Physics (see more in Albert Einstein 'The Lectures at Princeton').

23. Eratosthenes (276-194 BC) of the school of Alexandria. Greek geographer and mathematician whose map of the ancient world was the first to contain lines of latitude and longitude. His mathematical achievements include a method for duplicating the cube, and for finding prime numbers (Eratosthenes' sieve).

24. See for example, P. G. Michaelides,*"Polymorphic Practice in Science'* 1st Panhellenic Conference for the Didactics of Science and New Technologies in Education, organized by the Department of Education of the University of Thessaloniki, Thessaloniki, April 29 –May 1, 1998 (in Greek).

25. This technique was used for the first time in the Keck Telescope, situated on Mauna Kea, Hawaii. It has a primary mirror 10 m/33 ft in diameter, unique in that it is consisted from 36 hexagonal sections, each controlled and adjusted by a computer to generate single images of the objects observed. It received its first images Nov 1990. This telescope is jointly owned by the California Institute of Technology and the University of California.

26. It is a system of vessels in the human body that transports essential substances (mainly blood) to and from the different parts of the body. Blood flows in one direction from heart to the arteries to the tissues to the veins and back to the heart. The heart 'valves' assure this one direction. A closed system with a network of tiny capillaries carries the blood from arteries to the tissues to the veins. In birds and mammals, blood passes also to the lungs and back to the heart before circulating around the remainder of the body i.e. it is a double circulation, the small (to the lungs) and the large (to the tissues). Blood flows through 96,500 km of arteries veins and capillaries supplying oxygen and nutrients. The total blood quantity of a grown up human is about 6 lt. The blood pressure is often measured on the arteries for diagnosis since it is closely related to the force and rate of the heartbeat and the diameter and elasticity of the arterial walls. It is due to the muscular pumping activity of the heart. Blood pressure 12 means 12 cm Hg i.e. 12/76 atmospheres. There is the great blood pressure when the heart ventricle contracts (systole) and pushes blood to the arteries, which expand to accommodate it because the capillaries, acting as a pressure regulator maintain a constant flow to the tissues and do not permit the immediate passage of the blood pulsed into the arteries. The heart ventricle then relaxes and then expands replenished with blood returning from the lungs (diastole). During this time the arteries by muscular contraction maintain the blood flow to the tissues while the blood pressure gradually diminishes until (low blood pressure) the heart ventricle contracts again. Great/low blood pressures (systolic and diastolic pressures as they are termed) around 12/8 are considered as a healthy condition.

27. The pump must be of a reciprocating action like the lift pumps used in most wells to lift up water by an up and down movement. Gear or rotary pumps are not appropriate for this analogy.

28. In Primary Science curriculum on the systems of the Human Body, the use of mechanical models to demonstrate by analogy the workings etc. is advised.

29. Manual workers when tired used to drink one or two glasses of wine as a means of a rapid revival.

30. This is only a legal criterion. Physiological effects may be more accentuated for some persons. The example is an (educated) estimation only because other parameters are also involved.

31. The temperature degree centigrade (°C) was officially renamed Celsius in 1948 to avoid confusion with the angular measure known as the centigrade (one hundredth of a grade). The Celsius scale is named after the Swedish astronomer Anders Celsius (1701-1744), who devised it in 1742 but in reverse (freezing point was 100°; boiling point 0°)

32. Boltzmann Ludwig 1844–1906. Austrian physicist who studied the kinetic theory of gases, which explains the properties of gases by reference to the motion of their constituent atoms and molecules. He derived a formula, the Boltzmann distribution, which gives the number of atoms or molecules with a given energy at a specific temperature. The constant in the formula is called the Boltzmann constant. Its value is 1.380662 × 10-23 joules per Kelvin. It is equal to the gas constant R, divided by Avogadro's number.

33. Kelvin William Thomson, 1st Baron Kelvin 1824–1907. Irish physicist who introduced the Kelvin scale, the absolute scale of temperature. His work on the conservation of energy 1851 led to the second law of thermodynamics. He was also popularly known for his contributions to telegraphy, he greatly improved transatlantic communications. Maritime endeavours led to a tide gauge and predictor, an improved compass, and simpler methods of fixing a ship's position at sea.

34. These forces are the electromagnetic forces for the physical bodies, the nuclear forces for the nuclei, the gravitational force for the stars and galaxies, etc.

35. And you may understand why, when in a hurry and your morning tea is very hot its temperature will lower faster if you first stir it for as long as your hurry permits and then add the sugar and/or the milk than doing it in reverse.

36. Using this and making some further plausible assumptions, you may speculate if and how much the length of a flying Concord airplane is increased (the elongation is of the order of 0.4 m). Concorde is the only supersonic airliner, which cruises at Mach 2, or twice the speed of sound, about 2,170 kph/1,350 mph. Concorde, the result of Anglo-French cooperation, made its first flight 1969 and entered commercial service seven years later. It is 62 m/202 ft long and has a wingspan of nearly 26 m/84 ft. Developing Concorde cost French and British taxpayers £2 billion.

37. Otherwise zero speed would be the optimum and cars, especially fast moving family or transport cars would be banned.

38. This value corresponds to a car able to climb (or at least not slide back) a 45^o upward slope.