The balance of wisdom

Scales throughout some episodes of its history

If we look around us, we notice straight away that we can't do without balance and weigh, they are always needed everywhere: in industry and agriculture, in architecture and construction, in the shops, large and small, at the market and at home. That's why scales are one of the most ancient of instruments known in the history of humanity. Its use is confirmed for the oldest of times. In effect, archaeological searches often bring up pieces of scales: arms, receptacles, springs or counterweights, the smallest and the largest, the lightest and the heaviest.

From numerous illustrations that we have come across, as those discovered in Egypt and which date from three thousand years before our time; the word "balance" is represented there by a seated man, with a hand raised above his head. Several fragments of the Book of the dead, religious Egyptian texts, also show scales. They are, the most often, scales with two equal arms having two receptacles on each end of the beam and an axis in the middle of the beam. You also often find the counterweights in the forms of animals, balls or rings.

In ancient Greece, and later in the Roman Empire era, one used two types of balances: with equal arms, and unequal arms. Illustrations and numerous fragments of them have been conserved.

It was Greece that founded the science of "simple machines", comprising of the study of the lever, the pulley and winches, of the corner or of the screw. The lever is the most used. The great Greek savants, Archimedes (died in 212 B.C.) and later Heron of Alexandria (1st century), formulated the "principle law of the lever" : in order that the lever stays in equilibrium, the relation of the suspended weight on its extremities must be inversely proportionate to the relation of the length of its arms. The law of the lever is with the static base, the oldest branch of modern mechanics. But the balance arm is no more than a lever, this is why the science of balance and weight is founded on this law.

From Antiquity until the Middle Ages, one used two types of scales:
-Scales with equal arms, which has a beam with receptacles suspended at each of its extremities or two equal arms which rest on a support (see figure 1). The balance is in equilibrium if the weight of an object placed on one of its two receptacles is equal to the total weight of the counterweights placed on the other receptacle;

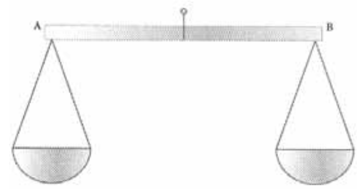


Figure 1

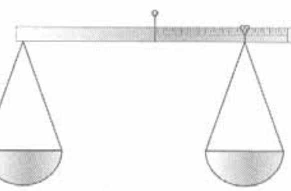


Figure 2

— Scales with unequal arms, which are found in two forms: a balance that is equipped with two receptacles of which one is fixed and the other, which contains the spring and counterweights, moves on the arm opposite to the first; a balance furnished with only one receptacle and one counterweight which moves the length of the arm opposite to the receptacle. On the latter, the receptacle could be replaced with a hook to weigh the objects on (see figures 2 and 3).

These two types of scales have formed the basis of all different models used in the medieval world at the time in the Muslim East and in Europe.

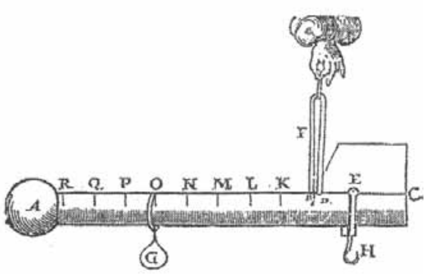


Figure 3

Numerous medieval Arab treatises have been conserved to the present day, describing different types of scales, from the most simple to the most sophisticated. From the IX century, the great mathematician Thâbit Ibn Qurra (died in 901) took an interest in the two types of scales with unequal arms described above: the qarastûn, with its two receptacles or its trammels to suspend the weight, and the qabbân, with its unique receptacle and its mobile counterweight. This second balance inspired the Muslim astronomers who invented a "balance-watch" based on the same principle and using, at the same time, the clepsydra principle (water watch).

The most interesting, among the scales with equal arms, and which are presented in different forms, is the hydrostatic scales, also called the "water balance", whose story starts with the era of Archimedes, when he discovered his famous law: "A body placed in water displaces a volume of water equal to the weight of the body submerged." A Greek legend recounts that Hiéron, the tyrant from the town of Syracuse, in Sicily, asked a savant to verify if his crown was made from pure gold or a mixture of gold and silver. In applying his law (that is to say weighing the crown in the air and then in water and comparing these weights with that of a piece of gold of the same volume), Archimedes discovered that it was made of a mixture of gold and silver (see figure 4, the weighing in water is not represented, but did take place).

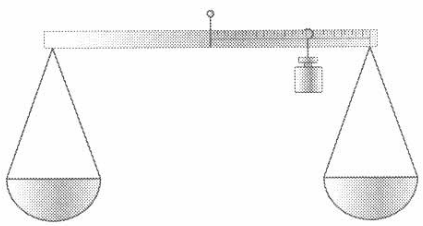
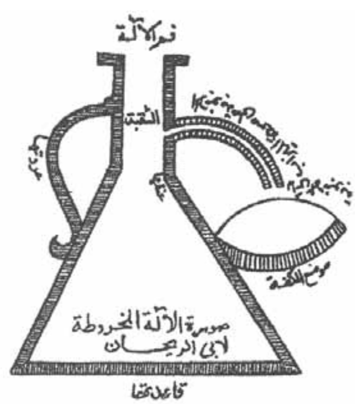


Figure 4

In the first half of the X century, al-Râzi (died in 923/4) perfected Archimedes scales. His "physical balance" with two receptacles, one of which was immobile, fixed at the end of the beam, the other could move along the length of the beam. After him, al-Birûnî (died in 1048) conceived an ingenious system to determine specific weights (also called "volume masses", that is to say the relation of the weight of each body to that of a same volume of water). It works with a receptacle combined with a counter balance: the small plaque on the right that is under the tube represents the tray of the balance).



The improvements made to the water scales were continued until the end of the XI century. As well as for scientific reasons, these improvements were motivated by the worry of the fight against false money exchangers and unscrupulous goldsmiths who had a tendency to substitute for precious metals (i.e. gold, and silver) some alloys which cost less. Among the perfectionists, there was the addition of a third tray. Two of the three trays were suspended, one above the other, so that you could weigh the subject body in the air (to get the correct weight) then in the water (to get the apparent weight, which reveals the specific weight with another body). The third, with counterweights, can move along the arms of the scales.

One of the innovators in this field, al-Isfizârî (XI century), introduced some new improvements and made a scales with five receptacles, that he called “the wise scales” or “universal scales”. This was composed of a cylindrical beam made out of iron or bronze about 2m long and had two equal arms, of two faces, of five hemispheric receptacles, of one moving weight and a fixed needle with a support, in the middle of the scales, fitted with a clever suspension system freely formed by the union of a transversal bar and a complicated formed piece called a “chisel” or “scissor”, freely attached by ropes. This suspension system was probably invented by al-Isfizârî himself.

This form of free suspension beam on a wall or on another plane vertical surface is very important. It reduced the friction effect. The scales high precision is assured by the correctly chosen dimensions of the beam and the needle, the flexing angle of the beam, the standard of the needle, etc.

All these contributions and others are brought together by the great Persian savant al-Khâzinî (XII century), the true founder of the theory of balance and weighing, in his book [Book of balance and wisdom.] In this important work, you can find the history of water scales dating from Antiquity. The author describes, in particular, the scales that would have been used by Archimedes (see figure 4) and he shows that this balance is only efficient if made out of an alloy of two specific metals. If it were made out of two different metals, it would need to have another balance. What’s more, you have to use special water, having a determined density.

Al-Khâzinî remarked also that, to obtain a precise balance, all parts have to have the correct dimensions: 4 elbows (angles) for the length of the beam (about 2m), 4 fingers (about 8cm) for the thickness in the middle of the beam (which should be more important than at the ends because it is there that the charge is at its maximum, 1 elbow (about 50cm) for the length of the needle, that is quarter of the length of the beam.

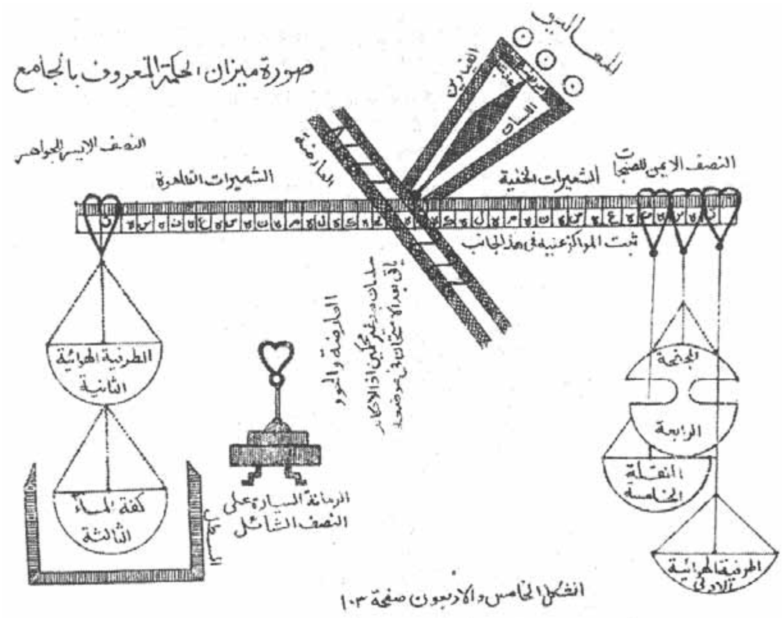


Figure 5

This savant even contributed to improve the "balance (scales) of wisdom". He dedicated an entire chapter to the description of the different parts, the method of assembly, the usage of it and the problems to be encountered with its equilibrium and precision. One of the models he has described has been built out of wood with metal receptacles (see figures 5 & 6).

These scales have two receptacles for weighing a body in the air free and a third for weighing in water.

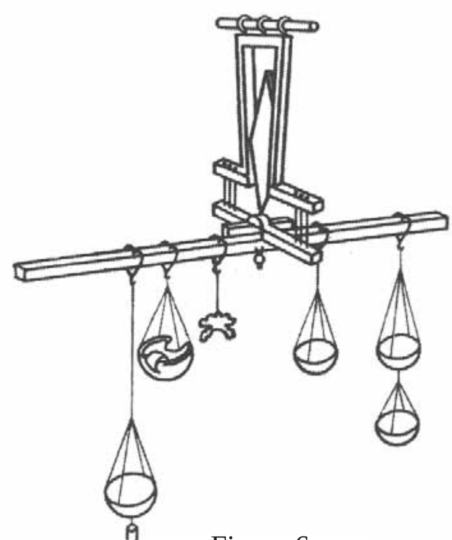


Figure 6

All three are fixed to the ends of the beam. To other receptacles are mobile. With the counterweights, also moveable, this allows the scales to be in a position of equilibrium before calibration and weighing. To optimise the weighing. it is necessary to use a series of crossed springs according to a geometric progression of 2 or 3, that is to say a series of crossed springs : 1, 2, 4, 8, 16, etc., or else 1, 3, 9, 27, 81, etc.

Al-Khâzinî also described in detail the method to weigh a body in water. Having weighed it, you set the scales to equal with the two receptacles and the moveable counterweights on the graduated beam. Then you reset the scales to level with the third receptacle fixed immerged in water. After that, you place the body, of a known weight, in the receptacle on the left arm, which is free in the air, and that is fixed above the receptacle immersed in the water. Next, transfer the body of this receptacle in the submerged receptacle and the counterweights in the moveable receptacle on the right. You set the balance to equal moving the non-fixed receptacles along the beam, on each side, so that the receptacles always stay equidistant to the axis. The place where you are, at the end of the operation, the moveable receptacle with the counterweights constitutes what we call the “centre” of the suspension (of a metal or a mineral), that is to say the point that corresponds to the specific weight of the object weighed (the animation on the website dedicated to the project helps you to understand the ingenuity of this.)

Repeat this exercise with several materials, the beam is graduated by the “centres” according to the order crossing the specific springs: first the metals (gold, mercury, lead, silver, bronze, iron, and tin), then the minerals, (sapphire, rubies, spinel, emerald, lapis-lazuli, rock crystals, and glass). then, you determine the particular conditions concerning the quality of the bodies studied and that of the water. It is necessary to use water from the same source and the air temperature should be constant.

The scales are also calibrated, you can weigh pairs of different metals and impure minerals. When you set the scales to equal twice, in weighing for example an alloy, the receptacle containing the alloy is found near the “centre” of the scale. If the body weighed is an alloy of metals, you can determine the percentage of the metals of which it is composed. If it is a mineral, this signifies that it is not pure or that it has hollows.

All this is only possible for alloys of two components. Al-Khâzinî notes that that the scales can be levelled in one manner only. In consequence, the specific weight of a given substance and the composition of a given alloy are determined in one way only. If the equilibrium of the scales is taken in several points on the beam or if you cannot set the scales to level, this signifies that the analysed substance is an alloy having three or more components, and if it is a mineral that it has hollows “caves”, etc. From a mathematical point of view, this problem does not have a single solution because it relates to an indefinite equation.

Finally we have to confirm that this instrument was called “universal scales”, because it allowed people to carry out different types of weighing and therefore to resolve numerous problems: problems in changes, the course of monies, the composition of alloys and mixes, and even applied mathematical problems. In effect, with the help of weights, and using pre-calculated tables, the scales allow us to resolve linear equations and some equation systems without calculation, simply reading the results on the scales.

The “balance of wisdom” were the most complete scales known in the Muslim world between the XII and the XV centuries, and perhaps even later.

Is it really gold?
On the discovery of "the balance of wisdom"

Objectives

Each material comprises of its own volume mass (in relation to the mass by volume).
One object that can turn around a fixed axis can stay equal if it is submitted to forces of which the effects are composed.
In order to turn the object, a great force has more effect than a small force applied at the same distance from the axis and an equal force has a positive effect if it is applied at a greater distance from the axis.

Reference to the project

Year 3 : "The man-made world: levers and scales, the completion of equilibrium".
College : "To measure mass, to measure the volumes".

Equipment used

Kitchen scales, Roberval scales, springs or graded rulers and elastic bands, graded receptacles (test tubes or beakers), water, bowls of varied mass, modelling clay.

How to distinguish gold from an identical yellow metal? This question was solved from the III century B.C. in Syracuse. In fact, it is possible to differentiate between two materials that look the same by comparing their "volume mass", that is to say their mass for a given volume. The five receptacle scales, called "scales of wisdom", created in the XI century by the Persian savant al-Isfizârî, is a measuring device of great ingenuity that allows, by the comparison of volume mass, to determine the nature of the material making up the majority of the objects. If the way it is used appears relatively simple (the animation on the project's website gives you a full picture), the scientific explanation of its function stays complex. In spite of everything, the physical notions puts into operation (apparent weight, mass, volume) around the principle of equilibrium. This principle is suitable for primary schoolchildren. The module that we are showing you has for its objective to make the pupils aware of the size of "volume mass" in running them through the historic stages in the building of the "scales of wisdom".

For the teacher

The volume mass of an object (measured in grams or kilograms per unit of volume) is a characteristic size of an object that depends solely on the nature of the material(s) of which it is made up. It is possible to calculate the volume mass of each object in dividing its Mass M (in grams or kilograms) by its volume V (in litres or in cubic metres). The result of this quotient (μ=M/V in g/l or in kg/l for example) is an invariant, that is to say for the same material and those that have the mass or the volume considered, the quotient M/V is a constant. The following stages comes up to this invariance and educates the pupils about the "volume mass" in a progressing fashion.

Activity 1 : To construct the size "volume mass"

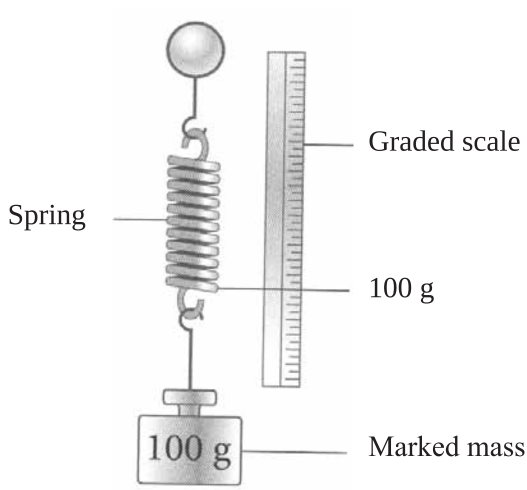
In the III century B.C., Hiéron II, king of Syracuse, commanded a crown to be made in gold, to be offered to the gods. He gave the goldsmith the quantity of gold necessary for the crown to be made from. The completed crown was weighed; its mass was identical with the amount of gold given. However, the king had his doubts: the crown did not appear to be of pure gold. Archimedes was charged to verify it but no damage was to be done to the work.

Thanks to an ingenious method, he showed that the crown was not made out of pure gold, but a mixture of gold and silver. What was this method? How did Archimedes uncover the subterfuge of the dishonest goldsmith? This module will let you uncover this.

Stage 1 : Measuring the mass

In the course of this activity, the pupils are going to discover that objects of a different nature and of an identical mass do not occupy the same place (that is to say they do not have the same volume). Each group of pupils have a glass bowl (or metal) and a large piece of modelling clay. They are told to make a bowl out of the clay which has the same mass as the glass bowl. After a few minutes of groping round they ask about the necessity for a device to measure objectively the size “mass” (measured in grams or kilograms, for example).

The idea of some scales comes to them in a fairly natural manner. A study of their books lets the pupils discover the different types of scales (scales with a beam, roman scales, springs, electronic scales etc.) and to explore the way they work. Each group of pupils studies a particular set of scales and what type of index it has (reading). The pupils then use the scales (Roberval scales, spring) given to them by the master in order to weigh the ball of clay.



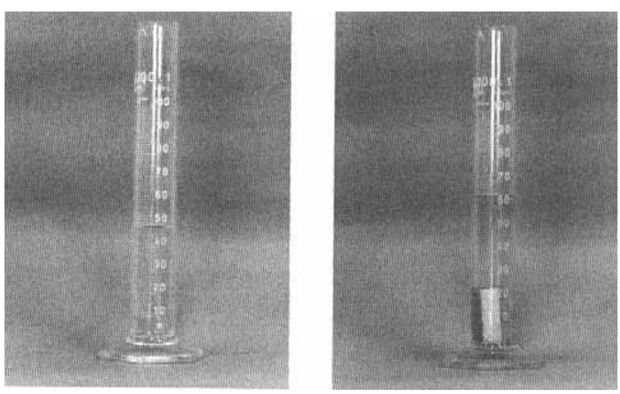
Mass of 100g suspended on a spring weight

There is a fairly simple way to measure the mass of an object. It suffices to suspend a spring (like the one on the spring weight) or an elastic band. In effect, the spring on the spring weight stretches under the weight of the object suspended from it (see previous figure). The heavier the object, the more the spring is stretched and vice versa. It suffices to calibrate it with marked levels (100g, 200g) and to establish the relationship between the tension of the spring and the value of the suspended (weighed) object. You can then find the weight (mass) of an object by reading the graded scale. After this little demonstration, you can suggest to the pupils to construct their own spring weight with the simple material. A ruler and an elastic band will do it!

The use of the spring-weight and the Roberval scales allows the pupils to get a piece of clay of the same weight as the glass bowl. They note that the two bowls are distinguished by the place they occupy, that is to say by their volume, it is possible to measure this (in litres, in millilitres or in cubic metres, for example).

Stage 2 : To measure the volumes

The pupils are now invited to think of an experiment that allows them to evaluate the area occupied by the two bowls: that of the glass and the modelling clay. This stage needs them to establish a link between the volume displaced by an object submerged and the object itself. Bring to mind some everyday occurrences such as having a bath to establish this link.



You can measure the volume of a solid in whatever shape or form
by using a graded test tube: the volume of water in
the test tube corresponds exactly to the volume of the object.

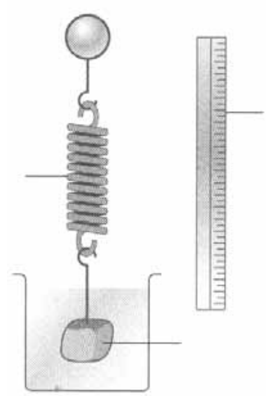
When you put an object into water, the level of the water rises to the equal quantity of the volume of the object immerged. So therefore it is possible to evaluate the volume of an object by immersion. This is the difference between the volume of water before and after immersion. In the example as shown on page 184, the volume of the object Vobject =Vwater after –Vwater before =15ml. This experiment allows the pupils to measure the volume of each of the two bowls.

The following stage consists of getting a clay bowl as the same volume as the glass bowl which they have. In such a configuration, the two bowls are distinguished by their mass: a new use of the scales allows us to verify the same volume, the mass of the two bowls is different.

The master explains to the pupils that there is a size that allows us to know how the mass of an object varies when you change its volume, and oppositely, without having to measure the two sizes each time. This new size is called the "volume mass", unique to each material; which allows us to distinguish one from the other. Suggest to the pupils to find the value of this size for the clay.

Stage 3: The research of an invariant: the volume mass

The pupils are told to make up a protocol for an experiment to characterise the evolution of the volume for the mass of modelling clay given using the spring-weight. A first piece of modelling clay is suspended from the spring of the spring-weight. The pupils take the reading off the graded scale and record it in a dual entry table. Then the piece of clay (still on the spring) is immerged in a graded receptacle (see figure). The difference of the volume before and after immersion is also recorded in the table (see later).



The use of a graded receptacle allows us to calculate the volume of the object immersed. When the clay bowl is immersed, the spring does not stretch as much, it appears lighter.

mass (in g)	25	50	100	125	175	200
volume (in ml)	12.5	25	50	62.5	87.5	100
quotient M/V (in g/ml)	2	2	2	2	2	2

The experiment is repeated with different sized pieces of modelling clay. The pupils quickly note that there is a constant co-efficient multiplier between the value of the volume and that of the mass (here the co-efficient is equal to 2). You can therefore write that, for the modelling clay, M = 2 x V or that the relation M/V = 2 = constant. This constant is “volume mass”. It is measured in g/ml or in kg/l and is owned by each material. This size is associated to that of the density: a denser object than another (its volume mass is bigger) if, for a same mass, it occupies a smaller volume. It is possible to compare the densities of objects of an identical mass by plunging them in water.

Stage 4 : the notion of “apparent weight”

The preceding operation necessitates several successive stages: the measurement of the mass of the object, that of its volume, then the calculation of the relation of the first to the second. Al-Khâzinî’s scales (and that created by Archimedes some centuries beforehand) reduce this succession of measurements and calculations in a unique action, that of measurement, not of the volume mass itself, but of a size that is directly associated to it: the “apparent weight” of the objects.

For the master: With the preceding activity, some pupils will have noticed that when you plunge the bowl of modelling clay in the water, whilst it is suspended on the spring-weight, the latter relaxes: the object appears less heavy (see the figure above). The spring-weight (or any other weighing device) thus gives its measurement, not of the weight, but of the apparent weight. The force of gravity having a downward pull, if the object is less heavy, it is because the water is exercising an opposing force, that is to say from the bottom to the top (this is called “Archimedes’ push”). In consequence, in the water, an object possesses an inferior weight to its weight in the air. The weight of an object immersed is called “apparent weight”. This depends on the nature of the fluid that it is immersed in and even of the object itself. Also the bigger the volume of an object is, the more its weight appears to be less. Also, when two objects have the same mass, it is the one that has the greater volume that has the lightest apparent weight, and therefore the lightest volume mass. The comparison of the apparent weight of the objects of identical mass allows the comparison of their volume mass. This is also what allows us to know if they have (or not) the same nature.

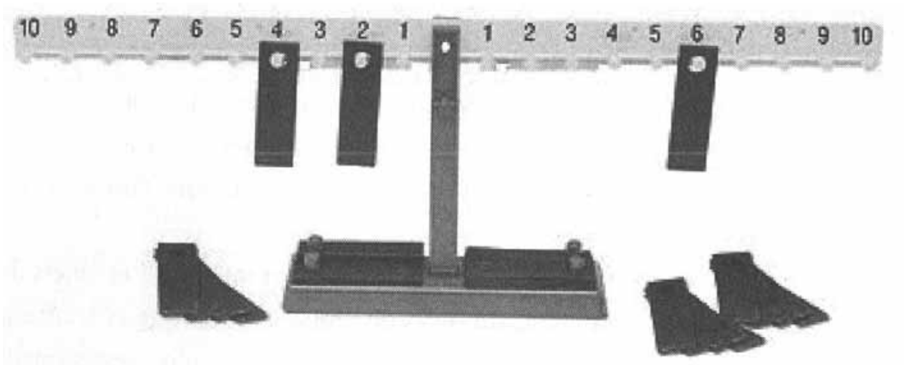
The pupils are invited to compare the apparent weight of two objects of identical mass. They choose an object of whatever mass and make a bowl out of modelling clay of the same mass. They suspend successively the two objects on the spring-weight. In the air, things change: the apparent weight of the modelling clay bowl is different to the one of whatever mass even if their mass is identical! The pupils form hypothesis on what has changed: the material, and therefore the volume mass of the two objects. From this fact, they gather that the volume of water displaced by the two objects is different. The object that has the higher apparent weight is the one that displaces the least water when it is immersed. To say it another way, it has the smallest volume, therefore the volume mass the most important (remember in effect that the volume mass μ is equal in relation to the mass M by the volume V : to equal mass, the smaller the mass the more the volume mass is big.) It is therefore possible to determine the nature of the objects of the same mass in comparing their respective apparent weight.

Activity 2 : To discover Archimedes' scales

To compare the apparent weight of the objects and to flush out the dishonest goldsmith, Archimedes used scales with equal arms called "hydrostatic scales". To bring the pupils up to the workings of Archimedes' scales it appears to us that we should go back to the equilibrium conditions of the scales.

Stage 1 : Equilibrium of the scales

For this, we use the scales called "mathematical scales" with a graded beam. Each graduation has a hook ready to hang on the plaques of identical mass.



The mathematical scale is equal when the graduated beam
is horizontal. Here, two plaques are respectively placed on the graduations 2
and 4 equalling having a plaque on the graduation 6 (Celda©).

This activity consists of a series of challenges to be taken up. Each time, the pupils have to think of a way in which they can dispose of a number of the plaques (of the same mass) to get the equilibrium. The challenges are:
— to equalise a plaque placed on the grade 3 with another plaque;
— to equalise two plaques placed on the graduation 2 with another plaque;
— to equalise a plaque placed on the graduation 6 with two other plaques without placing them on the same graduation (see photograph);
— to place a plaque on the graduation 4 and two plaques on the same graduation on the other side. Retain the equilibrium using the number of plaques you want.

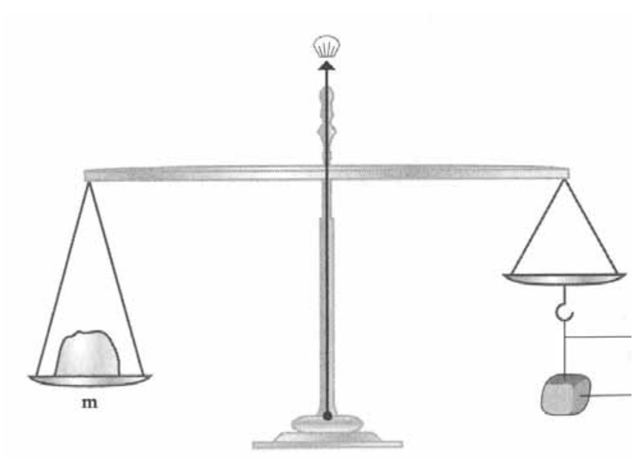
At the end of this activity, the pupils will realise that the equilibrium of the balance depends on the mass to be retained, but also their placement in relation to the rotation axis. Or yet, to equalise a mass with another twice as big, you have to place the latter twice as close to the axis.

Stage 2 : Archimedes' scales

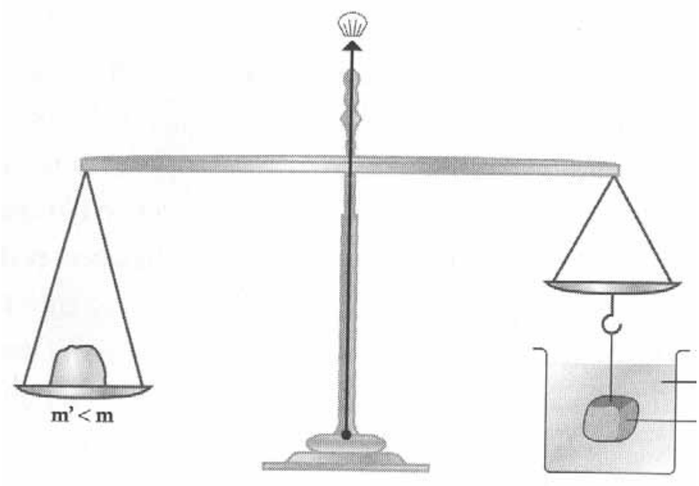
There is a relatively simple way to construct scales with equal arms. For this, you can use a rigid wooden beam that has a wire suspended in the middle. The wire is attached too a door knob, a window handle, . . . On side of this wire you suspend a small sachet containing some sand and on the other the object which you want to weigh. The pupils ensure that the balance is equal by trial and error.

Once this equilibrium has been established (see the below figure), the master asks the pupils to foresee what will happen when they immerse the object in water, whilst leaving it suspended from the balance beam, and checking their guess with the experiment. Confirming their attempt, the balance is distorted and the sand is spilled. They have to find a means to restore the balance. Several solutions are envisaged: perhaps they will refill the sachet (see following figure), perhaps they will move the sachet of sand towards the middle of the beam. Test the solutions.

The operation is then carried out again with the modelling clay bowl to the same mass as the object. When the object is not immersed, the equilibrium of the scales is obtained for the same quantity of sand in the same place as before the immersion. But things change when you immerse the bowl. The equilibrium is broken and to re-establish it, the previous solutions do not lead to the same results. If the apparent weight of the modelling clay bowl is heavier than that of the object, then the quantity of sand to re-establish it will be less, or, if it goes back to the same, the sachet will have to be moved to a shorter distance than it was previously.



When the balance beam with receptacles is horizontal,
the weight of the bowl is equal to a certain quantity of sand.



When you plunge the bowl in water, it is lighter.
The equilibrium of balance is made with less sand.

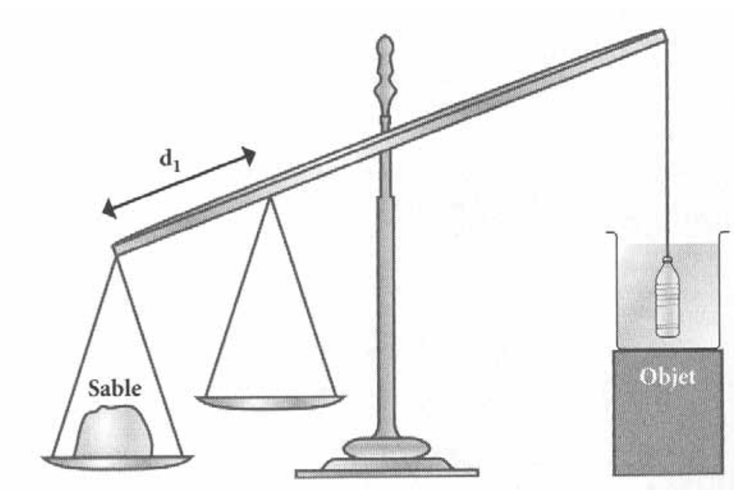
By comparing the quantity of sand used in both cases, or the distance of the sachet of sand from its original point, we obtain a reliable means to determine the nature of the two objects of identical mass without having to make successive measurements of mass then volume. This is the means Archimedes used to unmask the ruse of the dishonest goldsmith. . .

Archimedes carried out the following experiment: He put Hiéron's crown on the receptacle of the scales and the small weights on the other receptacle to obtain equal balance (equilibrium). Then he plunged the crown into water and noted that it was necessary to remove some of the weights to regain equal balance. Archimedes redid this with another object having exactly the same mass as the crown, but made solely from gold. He noted that when it was plunged into water, its weight did not diminish in the same fashion as in the preceding case and that the volume of water displaced was also different. He deduced from this that the crown could not be made solely out of gold! The goldsmith had therefore retained part of the gold that was entrusted to him and has replaced it with an identical mass of a less precious metal.

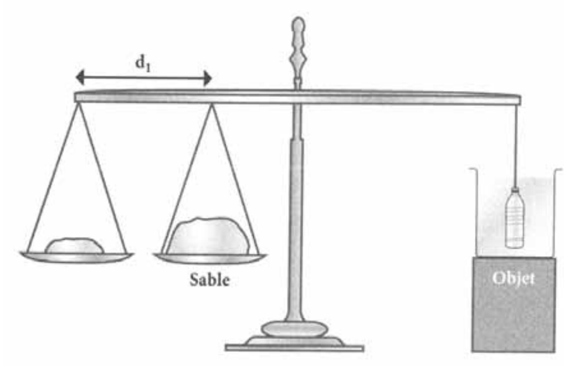
Activity 3 : In the footsteps of al-Khâzinî

Al-Khâzinî's scales allow us to get a more precise idea of the nature of the material. It comprises of a succession of levels and several receptacles. The objective of this activity allows the pupils to get to know the scales of wisdom but not to its full capacity. We will limit the study of the scales to four receptacles which allows us to classify from objects made out of the same material.

The pupils have an object again, a bowl made out of modelling clay of the same mass as the object and their lucky scales, they have an additional sachet (to gather the sand in) placed on the same side as the other sachet. The activity starts in the same way as the preceding one. The object is attached to one side of the scales. The equilibrium is obtained by placing a certain amount of sand on the other side. The object is then plunged into water, the beam leans to the side the sand is on (below). In order to re-equal (re-level) the balance, the pupils move part of the sand from the sachet furthest from the centre of the beam towards the other sachet. Equilibrium is once again obtained due to a certain quantity of sand placed in the other sachet, situated on the same side from the object at a certain distance d, from it (following page)

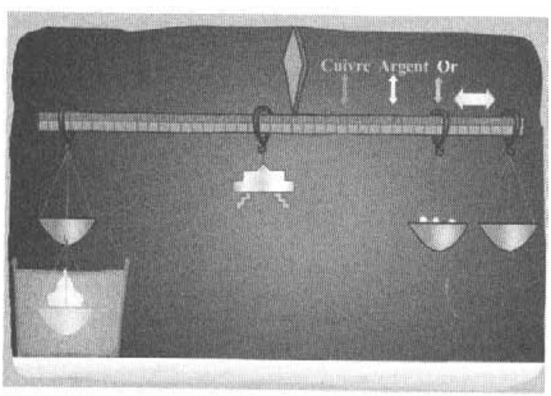


When the object is plunged into water,
its weight diminishes, the balance is not equal.



To re-level the balance, it is necessary to move a certain quantity of sand from the sachet furthest left to the right-hand sachet.

What will happen if you replace the object with the modelling clay bowl, while keeping the same quantity of sand in the same position? Knowing what happened in the previous activity, the pupils foresee that the equilibrium is going to be broken for the apparent weight of the modelling clay bowl is different from that of the object. The experiment is going to confirm this. The modelling clay and the object do not have the same volume mass, and the distance that separates the two sachets of sand is specific to each material. This is what the animation is going to confirm: the smaller the distance is between the two sachets of sand, the bigger the apparent weight is (therefore the bigger is the volume mass).



Extract from the animation: there is a relation between the distance between the two receptacles on the right and the material which makes the submerged object (on the left). This depends on the apparent weight of the immersed object, that is to say its volume mass.

In adding an additional receptacle, al-Khâzinî can determine the constitution of alloys, but the explanation of this revolutionary technique is down to the genius of al-Khâzinî and remains of a great complexity. It is not all it can do here.

The favourite game of Nabil and his sister Fadila was to resolve the enigmas which occurred when they were observing what happened around them, or in them. They were more passionate about this, than others of their time were, a little magic was about them, like the day when they were making a sort of fishing rod so that they could plunge stones in the water.

That day, Nabil and Fadila were hanging around a small lake in the rushes, not far from their hiding hole on the river bank. They had tied together several long beams of rushes so that they were rigid, before fixing some string to one of its ends. Then they had had the idea, so that the string was taut, to attach a stone and they enjoyed themselves by plunging it into the water and pulling it out as if they had caught a fish. Nabil became more and more active and finished by splashing his sister.

— Nabil stop, it's my turn! You're not achieving anything with the cane, I bet you never noticed that that the stones are less heavy when they are plunged into the water. To notice it, you have to put them in gently, like I do all the time!

— Anyway, I already know that. How do you think you can swim in water, otherwise? That would be impossible to do in the air!

Vexed by the supercilious manner of her brother, Fadila did not reply. She contented herself with issuing him with a challenge:

— Since you are so strong, can you show me how you can, without using your hands, plunge the stone in the water at the end of the string.

Very calmly, Nabil took the cane and held it out horizontally on his shoulder. Behind him, the long part of the cane balanced out the other shorter part, at the end of which was the string and the stone.

— Not bad! But watch out, now, I will change the stone, I'll put a bigger one on. What do you think, should I move the cane on my shoulder backwards or forwards?

Nabil started to slide the cane then it lost its balance, tangled up with the rushes strewn about the ground and fell in the water. Furious, he turned on his sister:

— But look, why are you giving me orders? You have not done it, with your little experiments!

Hiding her pleasure in outwitting her brother, Fadila looked at him knowingly:

— It's because you are bigger than me, so it is easier for you to make the balance!

— Oh well, if that's all, I am not a giant balance! Besides, I am going to make a proper one of them, like the merchants have! The stones that you chose will be passed without me having to do these ridiculous gymnastics. And they will have trays on the ends of the strings to put them on, as this will be easier than tying them on!

Fadila found her brother's idea so good that she had no further wish to mock him:

— Well done Nabil! And your scales, will it have two strings, eh, excuse me, two trays?

— Perhaps, but in the commercial centre, I have seen them with several trays, I wonder what they can be for. . .

— Well lets think about it and try several!

Occupied in thinking about how to achieve the object of their project, Nabil and Fadila had not seen the appearance of a man behind them whose clothes and turban was trimmed with gold threads, resplendent in the sunlight. He was carrying a leather bag full of mysterious objects and holding in one hand a receptacle full of water. On a finger on his other hand, scales were suspended. The clanks of his numerous trays finally made Nabil and Fadila turn around, surprised, exclaiming in chorus:

— Oh! what nice scales!

— From what I heard of your conversation, I think they could teach you a lot. I am called al-Khâzinî, and I have worked enjoyably to perfect this type of scales, as have several of my predecessors. I would be happy to give them to you as a present, if you are ready to learn how they work.

A big smile lit up their faces, Nabil and Fadila silently nodded their heads. Their eyes were shining in curiosity, they approached the man with the gold trimmed clothes. He put the bowl with water in next to them as well as other objects that he had with him in his bag, and started to assemble the scales trays, explaining as he went along. . .

What happened next has not come down to us, it was a long time ago, the memory is lost! It only remains that al-Khâzinî was the first one to perfect the scales with five trays, also called “the balance of wisdom”. And in one manner or another, as a long time ago he accompanied Nabil and Fadila, he will accompany today all of those who ask the same questions. In one way or another. . .

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