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Popularity and Relevance of Science Education for scientific Literacy

Am I being Cheated in the Market Place ?

Student Handout

Worksheet 1 Experiment 1

Take a piece of wood 50-100 cm in length. Tie a piece of string around its middle to form a loop. When lifted with this loop the scale should remain balanced, i.e. it should remain horizontal. If not move the string slightly until the piece of wood is balanced. The point at which the loop of string is tied to the scale is called the fulcrum. Note the position of the fulcrum and make sure it does not slip from this position throughout the experiment.

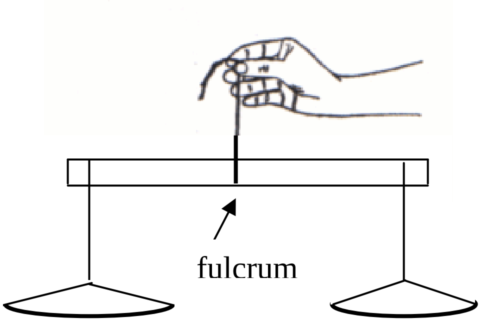

Fig 1

Take out 20, 30, 40 and 50 g weights. Tie a loop of thread around each weight as shown in Figure 2. You will use these loops to hang the weights from your scale.

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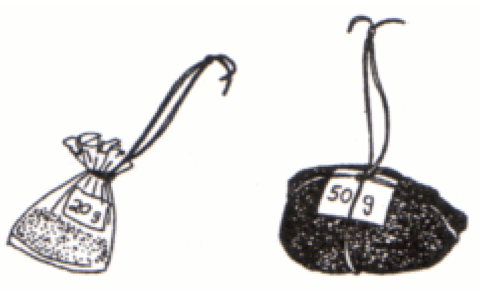

Fig 2

Place a 50 g weight on the scale at the end of the piece of wood. The loop of thread should hang straight over the mark on the end of a scale as shown in figure 3.

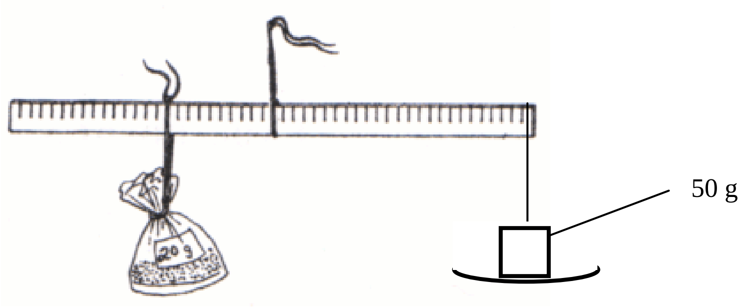

Fig 3

Hang a 20 g weight on the left hand side of the scale at such a distance that the scale is balanced when you lift it by the central loop.

How far from the fulcrum did you have to hang the second weight? (1)

Now change the right-hand weight. Slide the other weight till the scale is balanced again. Repeat this with other weights. Record your findings.

Now hang a weight on the right-hand side in place of the scale and complete the table give below.

What can you conclude about the distance of the weights from the fulcrum if the scale is to remain balanced? (3)

Left Hand Side of Fulcrum			Right Hand Side of Fulcrum		
Weight attached (g wt)	Distance from fulcrum (cm)	Weight x Distance (g wt x cm)	Weight needed to balance(g wt)	Distance from fulcrum (cm)	Weight x Distance (g wt x cm)
20	10	200	20		
20	15	300	20		
20	16	320	40		
20	24	480	40		
40	7	280	20		

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40	11	440	20		
30			60		

After entering all the observations you have taken so far, complete the table by calculating the necessary products. Compare the products on the left of the table with those on the right.

What do you find in each case? (12)

Is there any general conclusion that you can draw from the experiments you have done? Discuss this with your teacher and write it down in the form of an equation. (13)

If you find it difficult to come to a definite conclusion, you can take some more observations with a different weights hung from either side of the fulcrum.

Noting that the product of the weight x distance from the fulcrum is called the moment, express your conclusion from the table in terms of the moments of the left side versus the moment on the right side.

Worksheet 2 A puzzle

The pans of a pair of scales are the same weight as also are the weights placed in each of them. The scales still don’t balance.

Based on your experiences of the previous experiment, what can be the reason for this? (5)

Worksheet 3 Using a Spring Balance

Record the reading for various subjects using the spring balance and one of your home-made balances.

Record your findings in at least 6 different cases.

What conclusion can you make for the readings ?

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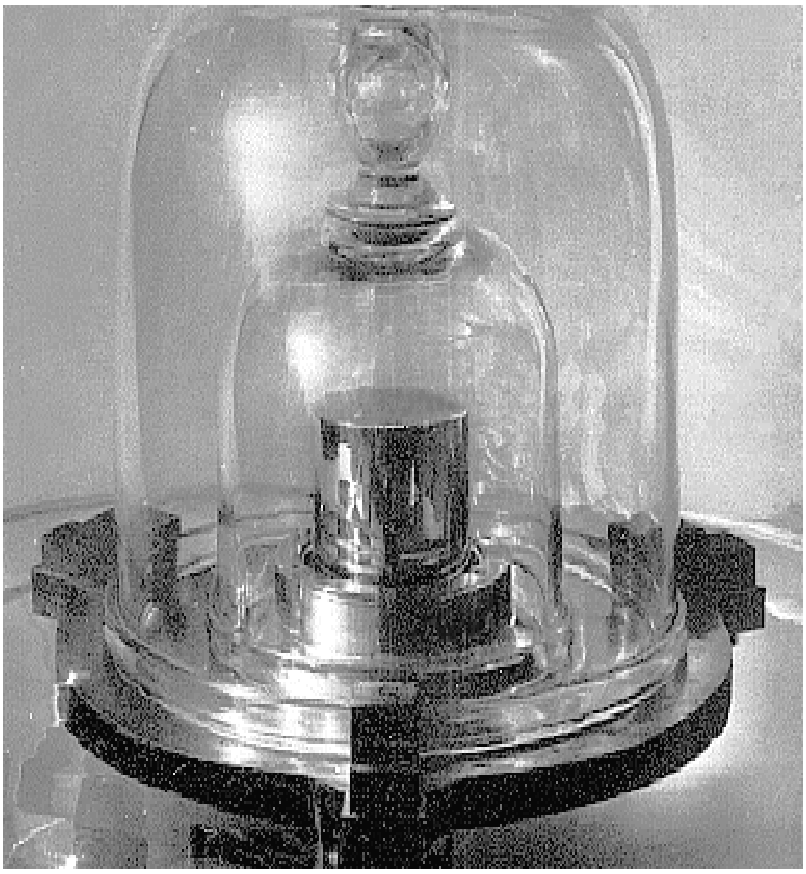
Kilogram

The unit of mass in SI, equal to the mass of the International Prototype Kilogram, a platinum-iridium cylinder kept at Sèvres, France. The present definition dates from the *1901* 3rd CGPM, though the Prototype was made in the *1880's*. About 2.2046 pounds avoirdupois. Symbol, kg.

The kilogram is one of SI's seven base units. It is unique in being the only SI unit still defined by a physical prototype, and the only one that incorporates one of the decimal multiplier prefixes in its name. To be completely consistent, the gram should have been the unit of mass.



History of the kilogram

The kilogram originated in the reforms of the French Revolution. Conceptually, it was to be the mass of a cubic decimeter of water at water's maximum density. It was originally called a *grave*, but the name was changed to kilogram in *1795*. In the same year Lefèfre-Gineau was given the job of determining just how massive a cubic decimeter of water was. In the meantime, a provisional kilogram was made which was expected to be close enough to the final value for commercial purposes.

The method that Lefèfre-Gineau chose depends on the principle that the difference between the weight of an object in air and its weight immersed in water is the weight of the water it displaces. He made a hollow brass cylinder, just heavy enough to sink in water, whose dimensions were measured repeatedly. After corrections were made for changes in size due to thermal expansion, the cylinder's volume was calculated to be 11.28 cubic decimeters at 0°C. To weigh the cylinder, special weights were made of brass of the same density as the brass of the cylinder, to compensate for the buoyancy in air of the weights.

After months of subtle and precise work, the researchers concluded that the mass of a cubic decimeter of water at its maximum density was 99.92072% of the mass of the provisional kilogram.

To create platinum standards for the new system of weights and measures, the former royal jeweller, Marc Etienne Janety (Janetti), was recalled to Paris. (He had fled when the revolution started.) By *1796* he was making kilogram masses. One of these, a cylinder 39.4 millimeters in diameter and 39.7 millimeters high, was legally declared the official prototype of the kilogram in *1799*. Since then it has been called the Kilogramme des Archives.

In the *1870s* the French government sponsored a series of conferences (*1870*, *1872*) to discuss how metric standards ought best be designed, produced and distributed. One of the conference's conclusions was that new standards ought to be made of a platinum-iridium alloy rather than pure platinum. The first attempts to do so were failures. The Metric Convention (*1875*), which led to the establishment of the BIPM, gave fresh impetus to the work, and preparation of the alloy was entrusted to the London firm of Johnson, Matthey, who specialized in precious metals. They did succeed in casting the alloy, the French produced standards from it, and the new standards were ready for distribution before the first CGPM in *1889*. This conference recognized one of the new platinum-iridium standards—the one whose mass most closely matched that of the Kilogramme des Archives—as the new prototype of the kilogram. It is that object, made in the *1870s*, which is referred to as the International Prototype Kilogram.

Modern measurements of the mass of water have shown that a cubic decimeter of water has a mass that is about 28 parts per million less than a kilogram—but that doesn't matter, because the kilogram hasn't been defined in terms of the mass of a cubic decimeter of water since *1799*, when the Kilogramme des Archives was accepted as the unit's prototype.

Future of the kilogram

The continued dependence of the kilogram on a physical prototype makes metrologists uneasy. The last time the International Prototype Kilogram was compared with the national standard kilograms, (*1988 – 1992*), it was less massive than the average of the masses of the national kilograms. The probable explanation is that the Prototype's mass has decreased, for some unknown reason, by about 30 micrograms over the past century. Besides, because of the risk of damaging it, the unique prototype can't be used very often—the use being comparisons with the various national standards laboratories' standard kilograms. Although currently the prototype meets all needs for accuracy, physicists have been searching for a way of defining the kilogram in terms of fundamental physical constants.

Scientists Struggling to Make the Kilogram Right Again

The kilogram is getting lighter, scientists say, sowing potential confusion over a range of scientific endeavor.
The kilogram is defined by the platinum-iridium cylinder No one knows why it is shedding weight, at least in comparison with other reference weights, but the change has spurred an international search for a more stable definition.
Even the apparent change of 50 micrograms in the kilogram -- less than the weight of a grain of salt or the weight of a fingerprint-- is enough to distort careful scientific calculations.

Any recommendation for change of the standard will be made by the International Committee on Weights and Measures, a body created by international treaty in 1875. The agency guards the international reference kilogram and keeps it in a heavily guarded safe in a château outside Paris. It is visited once a year, under heavy security, by the only three people to have keys to the safe. The weight change has been noted on the occasions it has been removed for measurement.

The kilogram is the only one of the seven base units of measurement that still retain its 19th-century definition. Over the years, scientists have redefined units like the meter (first based on the earth's circumference) and the second (conceived as a fraction of a day). The meter is now the distance light travels in one-299,792,458th of a second, and a second is the time it takes for a caesium atom to vibrate 9,192,631,770 times. Each can be measured with remarkable precision, and, equally important, can be reproduced anywhere.

The kilogram was conceived to be the mass of a litre of water, but accurately measuring a litre of water proved to be very difficult. Instead, an English goldsmith was hired to make a platinum-iridium cylinder that would be used to define the kilogram.

One reason the kilogram has lagged behind the other units is that there has been no immediate practical benefit to increasing its precision. Nonetheless, the drift in the kilogram's weight carries over to other measurements. The volt, for example, is defined in terms of the kilogram, so a stable kilogram definition will allow the volt to be tied more closely to the base units of measure.

A total of 80 copies of the reference kilogram have been created and distributed to signatories of the metric treaty. The sometimes colorful history of these small metal cylinders underscores how long the world has used the same definition of the kilogram.

Some of the metal plugs were issued to countries that later vanished, including Serbia and the Dutch East Indies. The Japanese had to surrender theirs after World War II. Germany has acquired several weights, including the one issued to Bavaria in 1889 and the one that belonged to East Germany.

Why was platinum-iridium used to make the kilogram?

Platinum-iridium was chosen as the material for the kilogram for a number of reasons.

Its high density (approximately 21.5 g/cm^3) means the artefact has a small surface area and therefore the potential for surface contamination is minimised. Its high density also means that it displaces a smaller amount of air than a kilogram of less dense material (stainless steel or brass for example). The weight-in-air of the kilogram (or any mass standard) depends to some degree on the density of the air in which it is weighed because the air (or any fluid in which it is weighed) exerts a buoyancy effect that is proportional to the volume of the artefact. Minimising the volume of the weight minimises the effect of a varying air density on the weight of the artefact.

The relatively inert nature of the material also minimises surface contamination and enhances the mass stability of the artefact. Platinum and its alloys are reasonably easy to machine, enabling a good surface finish to be achieved on the artifact that again reduces the effect of surface contamination. The addition of 10% iridium to the platinum greatly increases its hardness and so reduces wear.

How might the definition of the kilogram change in the future?

For the last 20 years there has been a considerable amount of work undertaken looking for an alternative, more fundamental, definition for the SI unit of mass - the kilogram - because of limitations in the stability, realisation and dissemination of the present kilogram artefact. In other areas of metrology, SI base units have been redefined as better techniques became available - such as using a laser to realise the unit of length - and either in step with or ahead of needs. But unfortunately in mass metrology no such opportunities exist and the new approaches to a fundamental re-definition are being forced by necessity. Other base units have simpler definitions, essentially based on one measurement (such as the wavelength of light for the metre) but unfortunately no comparably straight-forward definitions are in sight for the re-definition of the kilogram; they all involve a number of complicated measurements. At present four methods are being investigated for their potential to provide a new fundamental definition for the SI unit of mass - the kilogram.

The Watt balance

The first proposal for re-defining the kilogram was to link it via the SI unit for power - the *Watt* (equal to one joule per second). Bryan Kibble of NPL proposed using the *current balance* - that had formerly used to define the *ampere* - to relate the kilogram to a value for Planck's constant. The fundamental measurements necessary for the definition of the kilogram by this method are the *volt* (via the Josephson junction) and the *ohm* (via the quantised Hall effect). Measurements of length, time and the acceleration due to gravity are also necessary. There are currently four NMIs working on the *Watt balance* project; NPL in the UK, The National Institute of Standards and Technology (NIST) in the USA, METAS in Switzerland and BNM-LNE in France.

The Avogadro approach

The internationally coordinated *Avogadro project* will attempt to define a kilogram based on a fixed number of atoms of silicon. The mass of a sphere of silicon will be related to its molar mass and the Avogadro constant by the equation:

$$m = \frac{M_m}{N_A} \times \frac{V}{v_0}$$

where	m	is the calculated mass of the sphere
	M_m	is the molar mass of the silicon isotopes measured by spectrometry
	N_A	is the Avogadro constant
	V	is the volume of the sphere measured by interferometry
	v_0	is the volume occupied by a silicon atom

To calculate v_0 the lattice spacing of a silicon crystal must be measured by x-ray interferometry. The practical realisation of this definition relies on the calculation of a value for N_A, the Avogadro constant, from an initial value for the mass of the sphere. This value is then set and used subsequently to give values for the mass of the sphere, m. An added complication with this definition is the growth of oxides of silicon on the surface of the spheres - the thickness of the layer needs to be monitored (probably by elipsometry) and used to correct the value of mass m.

Optical engineers will form two perfect spheres (the roundest spheres in the world !!) from a 20-centimetre cylinder of exceptionally pure silicon that arrived in Australia. The silicon, which has taken three years to produce, was made in Russia and grown into a near-perfect crystal in Germany.

Scientists will use the spheres to determine how many silicon atoms make up a kilogram, and this will be used as the new definition — bringing the kilogram into line with other base units such as the meter and the second, which are all defined by physical constants.

This means the diameter of the sphere varied by an average of only 35 millionths of a millimeter, making it a top contender for the title of the roundest object in the world.

Ion accumulation approach

This third approach to the re-definition of the kilogram involves the accumulation of a known number of gold atoms. Ions of Au^{197} are released from an ion source into a mass separator and accumulated in a receptor suspended from a mass comparator. The number of ions collected is related to the current required to neutralise them - supplied by an irradiated Josephson junction voltage source. The mass of ions M is then given by the equation:

$$M = \frac{n_1 . n_2 . m_a}{2} \int_0^t f(t) dt$$

where n_1 and n_2 are integers

m_a is the atomic mass of gold

$f(t)$ is the frequency of the microwave radiation irradiated onto the Josephson junction

m_a 197 u, for gold isotope Au^{197}, where u is the atomic mass (equal to 1/12 of the mass of C^{12})

Levitated superconductor approach

Like the 'Watt' balance project, this method relates the kilogram unit to electrical quantities defined from the Josephson and quantised Hall effects. In this technique a superconducting body is levitated in a magnetic field generated by a superconducting coil. The current required in the superconducting coil is proportional to the load on the floating element and defines a mass (for the floating element) in terms of the current in the superconducting coil.

Even from these brief descriptions of the four methods, it can be seen that the present approaches to the redefinition involve a number of demanding measurements. Almost all of these measurements must be performed at uncertainties which represent the state of the art (and in some cases much better than those currently achievable) to realise the target overall uncertainty of 1 part in 10^8 set for this work. The absolute cost of the equipment also means that the ultimate goal of all national measurement institutes being able to realise the SI unit of the kilogram independently will, on purely financial grounds, not be achievable.

All four approaches require traceability to a mass in vacuum, both for their initial determination and for dissemination