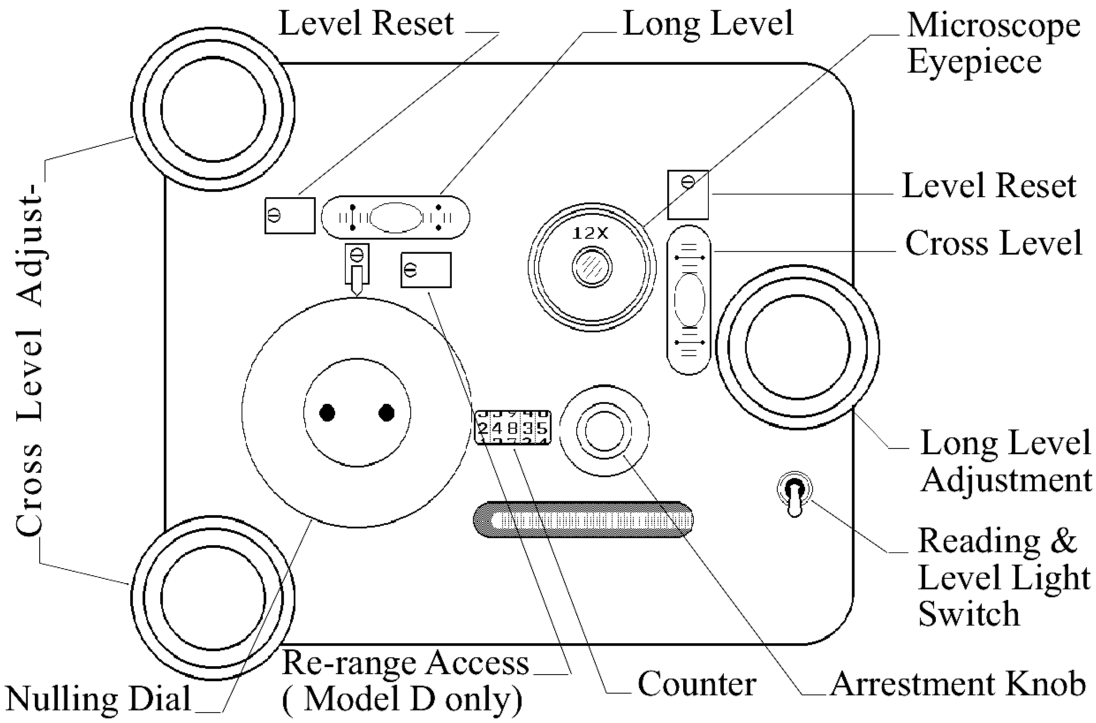
The top of the gravity meter



Important: No gravity meter should ever be moved without first clamping the beam

This diagram shows a typical LaCoste and Romberg gravity meter. The interior is very similar for all models but the outside may look a little different:

(i) G-275 has adjustable screw feet operated from the bottom. D-145 and G-128 have screws passing right through the instrument case and operated with knobs from the top, as shown in the above diagram.

(ii) D-145 has two internal screws and two nulling dials. Use the dial which the demonstrators tell you to use: the other should be left locked.

(iii) D-145 has electronic levels whose position is shown by galvanometer dials on the top. These are more precise than the spirit levels and should be used. Inform the demonstrators if the spirit levels are badly out of agreement with the galvanometers.

(iv) D-145 and G-128 have a facility for showing the beam position from a galvanometer dial labelled “beam”. It is easier for a group to see, and more precise, but is less reliable: it can go out of adjustment. If you use it, you should check that the reading in the microscope agrees with it.

How to make a measurement of gravity

(i) Place the concave levelling dish on the ground. On soft ground, push its feet firmly into the soil. On very soft ground, make a hollow in the ground so that the dish just rests on its rim. (On very soft ground, you will then have to keep very still while making the measurement, because moving your weight will tilt the ground and thence the meter.)

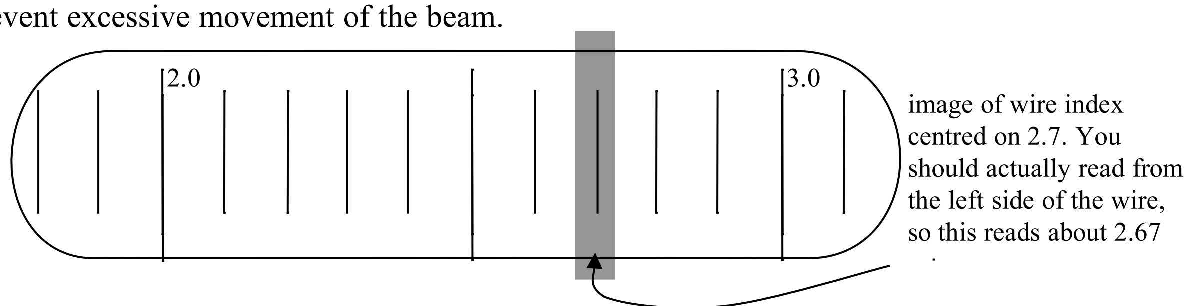
(ii) Before lifting the meter from its carrying case, check that the small knurled knob has been rotated fully clockwise by the previous operator so that the beam is clamped. Switch on the bulbs to light up the levels.

(iii) Lift the meter from its carrying case and position it on the concave levelling dish so that it is approximately level. The closer you get it to level at this point, the easier you will find the next step.

(iv) First, centre the right-hand side (cross) spirit-level bubble by adjusting either one of the two screw feet on the left. Only then should you try to centre the other (long) level by adjusting the single screw foot at the right. The instrument D-145 also has more precise electronic levels whose output is displayed by galvanometers - final adjustments should be made to get both of these galvanometers centred, even if this appears to make the optical levels off centre.

(v) **Unclamp** the beam by rotating the small knurled knob gently **anti-clockwise** until the stop is reached.

(vi) A wire index will be seen in the field of view of the microscope near an eyepiece scale reading of 2.4 or 3.8 for the meter G-275. The corresponding eyepiece graticule marks are 1.9 and 3.3 for the instrument D-145. These positions correspond to safety stops which prevent excessive movement of the beam.



(vii) If the index is not already stationary near the lower stop, wind the micrometer dial anti-clockwise until it is. Then rotate the dial slowly clockwise (dial number increasing) until the wire index is centred upon the required eyepiece scale division (printed on a label on the meter) A clockwise rotation of the micrometer dial will ultimately move the index from left to right and vice versa. Apart from reading fractions of a dial turn from the dial, the whole number of rotations of the micrometer screw must be read from the revolution counter next to the dial. The last digit of the rev counter should correspond to one tenth of a dial turn. With a skilled observer, the balance conditions can be reproduced consistently to about 1/4 of the smallest divisions on the micrometer scale. The photographs on the next page show what the view down the eyepiece looks like as the balance point is approached.

(vi) The null position must always be approached from below to avoid backlash errors. If you overshoot, wind the micrometer back at least one dial turn and start again. (You can go faster the second time as you can wind forward to almost the point where you overshot.) Remember that the beam has a free period of many seconds and that it will not respond instantaneously to a dial rotation when near the null position. Therefore make small adjustments to the micrometer position and always wait for the index to drift to the new equilibrium position before making further adjustments.

(vii) Some meters have a galvanometer which indicates the point of balance. This is a useful addition, but you should always check down the eyepiece to confirm that the galvanometer is working properly.

(viii) Very occasionally the beam may adhere to one of the stops. It can usually be freed by reclamping and unclamping, or winding the micrometer well past the null position. If all else fails, tap the case very gently with your finger-tip.

(ix) Check that the levels are still correctly adjusted then ***clamp the beam*** by rotating the small knurled knob fully ***clockwise***. Read the micrometer scale (example:- 4986.763 dial units, noting that the fifth digit on the revolution counter corresponds to one tenth of a dial turn).

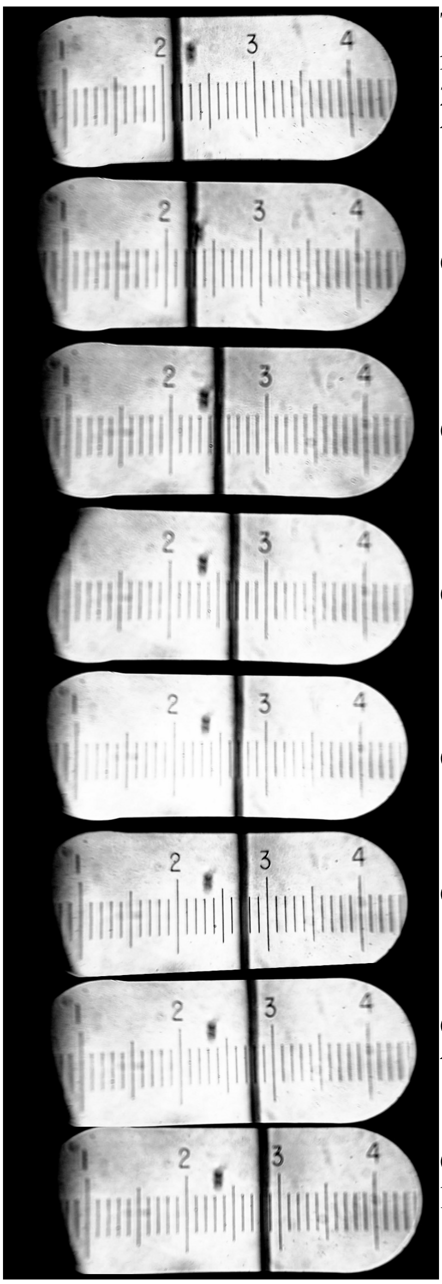
The reading is recorded as **4986.763**

Whole dial turns from the rev counter ↑ ↑ ↖ fractions of a dial turn from the dial

7 is the fifth figure on the rev counter but should be read from the dial

An exact calibration table is supplied by the makers to convert dial turns to physical units. As soon as you have finished reading, reclamp the meter so that it is again protected from vibrations and shock.

(x) Replace the meter in its carrying case and then switch off the light. The meter must always remain connected to its power supply so that its internal temperature of about 50℃ is exactly maintained. Take great care about this because it takes at least 4 days for the instrument to reach thermal equilibrium again: a loss of power for only a few minutes can cause disastrously high drift rates.



This figure shows photographs looking into the eyepiece of meter G-275 as it is balanced. The reading line of this meter is 2.70. Here, the cursor reads 2.1, so we need to turn the dial to the right ...

Cursor reads about 2.2 so keep turning.

Cursor reads about 2.45: keep turning

Cursor reads 2.6: keep turning in small increments

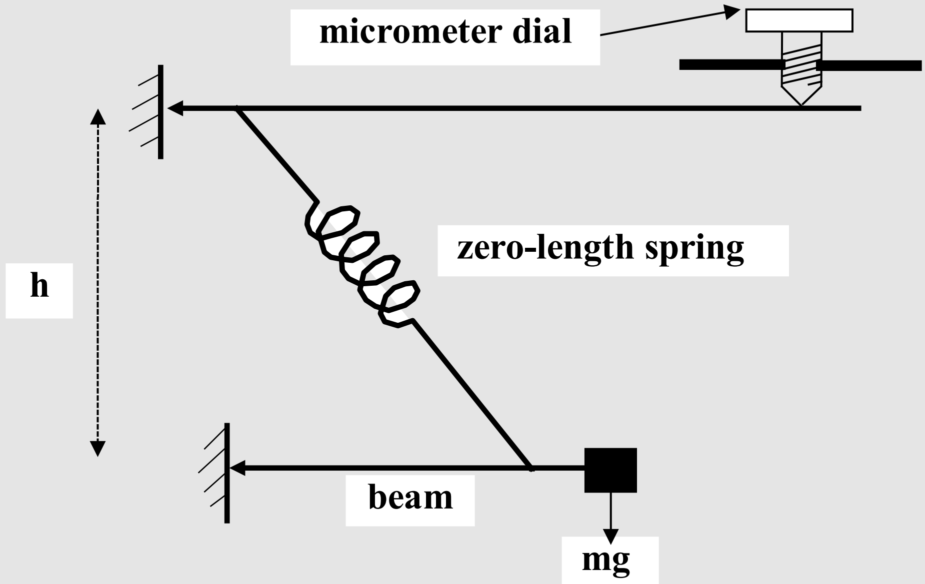
Cursor reads 2.65: turn dial a tiny bit further to the right

Cursor reads 2.70. That's it. Stop there and read the counter

Cursor reads 2.73: We went a tiny bit too far. Turn dial a whole turn to the left and start all over again.

Cursor reads 2.8: we went too far. Turn dial a whole turn to the left and start all over again.

How the LaCoste Romberg gravity meter works



The LaCoste & Romberg gravity meter uses the principle of an astatic pendulum. (In this context, ***astatic*** means that a background value of gravity is counter-balanced and the pendulum only responds to deviations from this value.) A horizontal beam, pivoted at one end, is supported by a 'zero-length' spring. This supplies an exactly constant torque independently of its tension or the deflection of the beam. Such a spring will therefore support only a constant weight $m\,g_o$ and any increase or decrease in weight due to a variation of gravity $[m(g - g_o)]$ would cause it to extend or contract catastrophically. (A ***zero length spring*** is one which has been prestressed during construction so that above a critical tension, the tension versus length curve is a straight line, with slope k (see below), which can be extrapolated to pass through the origin). By making the effective natural length not quite zero but a very small positive value, the beam will still balance for gravity values very slightly different from g_o, but in a non-horizontal position. In the LaCoste Romberg instrument the beam can be balanced horizontally for values of gravity other than g_o by means of a system of levers which changes the geometry of the spring support. A measurement of gravity is made by adjusting the position of the spring supports with a micrometer so as to bring the beam back exactly to a horizontal position: the micrometer is adjusted until a fine wire pointer attached to the beam is aligned with the optical axis of a microscope. When the beam is balanced horizontally, the balance condition is

$$g_0 = \frac{kh}{m}$$

In order to achieve the necessary accuracy, the instrument incorporates a very high degree of temperature compensation to avoid changes in the length or elastic constants of the beam and springs. Variations in air density which change the buoyancy force have to be compensated for. All working parts of the LaCoste Romberg instrument are made of the iron nickel alloy super-elvinar, which has a very small thermal expansion coefficient. In addition, the whole mechanism is enclosed in an air-tight, thermostatically controlled oven. Although temperature compensation is essentially perfect a very small residual drift always remains owing to creep in the components. When properly used, drift rates as low as 0.2 gu per month are attainable. (1 gravity unit (gu) = 10^{-6} m.s^{-2} = 0.1 mGal). However, since all alloys of the invar group are mechanically unstable, they are prone to creep instability if shocked or subjected to even quite moderate vibration levels. Therefore the instrument should be handled gently and protected from shock and vibrations.