

Centre of mass, impulse and momentum with calculus

AP Physics C (Mechanics and E&M, calculus-based) · Lab

Name: _____ Date: _____ Class: _____

A loaded rule balances exactly at its centre of mass. By measuring where several different loads balance, you can check the formula for the weighted average position and see how large the unavoidable errors are in a simple set-up. The sample data come from a rule of mass 0.100 kg.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:M Unit 4

Aim

Test the formula $x_{\text{cm}} = \Sigma mx / \Sigma m$ by loading a metre rule with extra masses and comparing the calculated balance point with the position where the rule actually balances.

Equipment

- Uniform metre rule with its mass measured (0.100 kg here)
- Slotted or labelled masses: 50 g, 100 g, 150 g, 200 g, 250 g
- Adhesive tape or loops of thread
- Knife-edge support, such as a ruler on its edge or a pencil on a table
- Second rule for reading positions

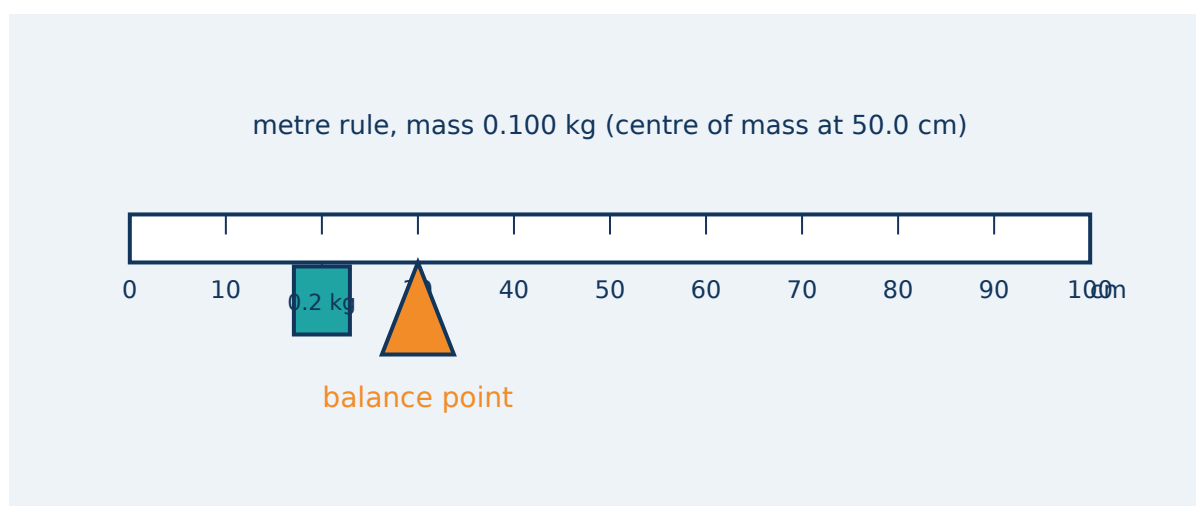
Safety

Safety

Keep fingers away from the edge when the rule tips, and work over a table with a padded surface so that masses do not fall onto feet. Do not use sharp blades as a support.

Method

1. Balance the bare rule on the support and record its balance point to check it is at 50.0 cm.
2. Tape the first mass at the stated position, as in the figure, and slide the rule over the support until it balances horizontally.
3. Read the balance position to the nearest 0.1 cm and record it.
4. Repeat for the other loads in the table, then calculate the expected position for each.



Loaded metre rule balanced on a support.

Results

Trial	Added mass (kg) at position (cm)	Measured balance point (cm)
1	0.050 at 90.0	63.0
2	0.200 at 20.0	30.3
3	0.100 at 80.0 and 0.100 at 10.0	46.5
4	0.150 at 70.0	62.2
5	0.250 at 30.0	35.5

Analysis questions

Question 1 Calculated position

For trial 1, calculate x_{cm} using the rule at 50.0 cm and the added mass, and compare it with the measured 63.0 cm.

Question 2 Complete the table

Calculate the expected balance point for trials 2 to 5.

Question 3 Differences

Find the difference between measured and calculated values for each trial and the percentage difference.

Question 4 Pattern of errors

State whether the differences show a systematic error or random scatter.

Question 5 Why balancing works

Explain why the rule balances when the support is at the centre of mass.

Question 6 Uncertainty

The position of the balance point is uncertain by ± 0.3 cm. Compare this with the largest difference.

Question 7 Better precision

Propose one modification to the procedure that would give a tighter match with the calculation.