

Using the ruler in the photograph shown below, determine the diameter of the tennis ball including uncertainty. Note that the finest divisions on the ruler are in 1 mm increments.



SOLUTION:

Even though the ruler's divisions are in 1 mm increments, the photograph's resolution is too poor to clearly make out the divisions. A much more reasonable measurement least count is 5 mm since these increments are more easily seen. Using this least count, the left side of the tennis ball, l_L , is located at 50.2 ± 0.25 cm and the right side, l_R , is located at 56.7 ± 0.25 cm. The diameter, D , is:

$$D = l_R - l_L = 56.7 - 50.2 \text{ cm} = 6.5 \text{ cm} \quad (1)$$

The absolute uncertainty in the diameter is:

$$\delta D = \sqrt{(\delta D_{l_R})^2 + (\delta D_{l_L})^2} = \sqrt{\left(\frac{\partial D}{\partial l_R} \delta l_R\right)^2 + \left(\frac{\partial D}{\partial l_L} \delta l_L\right)^2} \quad (2)$$

where

$$\frac{\partial D}{\partial l_R} = 1 \quad \text{and} \quad \frac{\partial D}{\partial l_L} = -1 \quad (3)$$

Thus,

$$\delta D = \sqrt{(\delta l_R)^2 + (\delta l_L)^2} = \sqrt{2(0.25 \text{ cm})^2} = 0.35 \text{ cm} \quad (4)$$

Thus, the tennis ball diameter, with uncertainty, is:

$$\boxed{D = 6.5 \pm 0.35 \text{ cm}} \quad (5)$$

Note that the International Tennis Federation (the United States Tennis Association is a member of this organization) indicates that a tennis ball should have a diameter between 6.541 and 6.858 cm for Type 1 (fast speed) and Type 2 (medium speed) balls (Type 3 (slow speed) balls are bigger). The measurement given above is within the upper limit, but could potentially be smaller than the allowable size.

Reference

International Tennis Federation, *The Rules of Tennis*, available at:

http://dps.altcd3.va.twimm.net/usta_master/usta/doc/content/doc_13_4198.pdf
(2005 Dec 15).